NUTRITION AND CANCER, *55*(2), 126–131

REPORTS

Curcumin Content of Turmeric and Curry Powders

Reema F. Tayyem, Dennis D. Heath, Wael K. Al-Delaimy, and Cheryl L. Rock

Abstract: *Curcumin, derived from the rhizome* curcuma longa, *is one of the primary ingredients in turmeric and curry powders that are used as spices in Middle Eastern and Asian countries, especially on the Indian subcontinent. More recently, laboratory studies have demonstrated that dietary curcumin exhibits various biological activities and significantly inhibits colon tumorigenesis and tumor size in animals. Curcumin displays both anti-inflammatory and antioxidant properties, giving it the potential to be considered in the development of cancer preventive strategies and applications in clinical research. Experimental studies have shown the biological activities of the compound, but much more information on pharmacokinetics, bioavailability, and food content are needed. Whether the amount of curcumin in turmeric and curry powders is sufficient to suggest effects on biological activities and cancer risk is unknown. To determine and compare the quantitative amounts of curcumin that are present in several brands of turmeric and curry powders, a high performance liquid chromatography technique was used to analyze 28 spice products described as turmeric or curry powders and two negative controls. Pure turmeric powder had the highest curcumin concentration, averaging 3.14% by weight. The curry powder samples, with one exception, had relatively small amounts of curcumin present, and the variability in content was great. The curcumin content of these seasoning products that are consumed as a component of the diet should be considered in evaluating baseline tissue concentration and response to curcumin supplementation, which is under study in chemoprevention trials.*

Introduction

Turmeric, a derivative of the plant, *curcuma longa*, a member of the ginger family, is a spice commonly used in Middle Eastern countries and other regions of Asia. It has a long history of use in herbal remedies, particularly in China, India, and Indonesia. The major curcuminoids, curcumin, demethoxycurcumin, and bisdemethoxycurcumin, occur naturally in these curcuma species. Curcumin, an active component of turmeric, is a yellow pigment that has been isolated from the ground rhizome part of the curcuma plant species, zingiberaceae (1,2).

Curcumin has been shown to have several biological effects, exhibiting anti-inflammatory (3–6), antioxidant (5,7–10), and hypolipidemic (11–13) activities. Curcumin has also been studied extensively as a chemopreventive agent in several cancers (14–17). Additionally, it has been suggested that curcumin may contribute in part to the lower rate of colorectal cancer in Asian countries compared to rates in other countries (18).

Curcumin exhibits relatively low oral bioavailability in humans and rats and may undergo extensive intestinal metabolism (1,5,19); absorbed curcumin undergoes rapid first-pass metabolism and excretion in the bile (1,5,15,19–20). In rats, curcumin absorption from the intestine has been reported to be about 60% (20). In contrast to the report of low bioavailability in most human studies, Cheng et al. (21) reported that a high oral dose of curcumin (0.5–8 g/day) for 3 mo resulted in increased serum curcumin concentration to a peak at approximately 1–2 h, followed by a decline within 12 h after consumption. A dose of 8 g/day resulted in a peak serum concentration of 1.75 ± 0.80 (mean ± SD) μM in that study.

Traditionally turmeric is used in various cuisines for flavor as well as a coloring agent for foods such as rice, yogurt, and chicken. Turmeric may also be used by itself or in combination with other mixed spices. Curry powder is a mixed spice with turmeric as one of the principal ingredients.

Curcumin content is reported to vary from one batch of turmeric powder to another. The percentage has been estimated to be between 1.06% and 5.70% in 4 different "commercially available" turmeric samples (22). In this prior anal-

R. F. Tayyem is affiliated with the Clinical Nutrition and Dietetics Department, Allied Health Sciences Faculty, The Hashemite University, Al-Zarqa', Jordan. D. D. Heath and W. K. Al-Delaimy are affiliated with the Cancer Prevention and Control Program, Moores Cancer Center, University of California, San Diego, La Jolla, CA 92093. C. L. Rock is affiliated with the Department of Family and Preventive Medicine, University of California, San Diego, La Jolla, CA

ysis (22), however, it was not clear if the turmeric powders were the types available to the commercial blenders of spices or to the consuming public. Several studies have shown that soil factors, including nutrients and level of acidity as well as the genus diversity, may affect the content of curcumin in plants that are the source of turmeric (23–24). Curry blends vary widely from one manufacturer to another, and numerous blends are available in shops and markets. Curry blends are usually composed of coriander seeds, turmeric, chillies, cumin seeds, fenugreek seeds, fennel seeds, trifala and nagkeser (fragrant spices), cloves, cassia, garlic, curry leaves, and salt.

To our knowledge there are few data available on the curcumin content of turmeric and curry powders. The aim of this study was to quantitate curcumin in various sample blends of turmeric and curry powders. These blends of spices were purchased in several grocery stores in the Riverside, Orange, and San Diego Counties of Southern California. Information about the curcumin content of turmuric and curry powders is a useful first step toward estimating the amount of curcumin that could potentially be obtained from the diet and specific food choices.

Materials and Methods

Chemicals, Reagents, and Sample Preparation

Turmeric, curry powders, and cardamon were purchased from local grocery stores, including some that catered to the Middle Eastern and Asian Indian Communities, in Southern California.

Acetonitrile, methanol, acetic acid, deionized water were purchased from Fisher Scientific (Pittsburg, PA). All reagents were of analytical grade. Mobile phase reagent containing the following ratio (volume:volume) mixture of acetonitrile:methanol:water:acetic acid (40:23:36:1) was prepared according to the method of Heath et al. (25). Five mg of each powdered spice were weighed on a Mettler model AB204 balance (Mettler Instrument, Hightstown, NJ) and dissolved in methanol, making a precise final volume of 5.0 mL with mobile phase reagent to achieve the desired concentration, 1,000 µg/mL. Next, the dissolved solution was centrifuged in a bench top Centifuge (Sorvall RT 6000D, Dupont, Waltham, MA). An aliquot was removed and further diluted prior to column injection.

Curcumin was separated and quantitated by isocratic high performance liquid chromatography (HPLC), using ultraviolet detection at a wavelength of 262 nm. An aliquot (50 µL), was injected onto a reversed-phase column, and the HPLC system consisted of a 410 auto-sampler with refrigeration unit, a 9050 UV visible detector, and a 9010 solvent delivery system with Star 6.30 Chromatography Software (Varian, Walnut Creek, CA). Chromatographic separation was accomplished using a Waters SymmetryShield 3.9 × 150 mm, 5-µm C_{18} column (Waters, Milford, MA). The column was coupled to an Alltech absorbosphere 30 × 4.6 mm C_{18} guard column (Alltech Associates, Deerfield, IL). The flow rate was 1.0 mL/min.

The quantitation of curcumin is by peak area and is based on a standard curve in a methanol matrix, generated by using pure external standard. A linear curve is generated from a single analysis of six different standard concentrations. All samples were analyzed in triplicate.

Results

In our analytical processing of the turmeric and curry powders achieved by dissolving the powders in analytical grade methanol, we did not detect any interference with the peak of interest, curcumin. The chromatographic retention time of 5.4 min was consistent with and identical to the known curcumin external standard.

The curcumin contents of the selected brands of turmeric and curry powders are shown in Table 1. Product identification information, including brand names, ingredients, and manufacturers is shown in Table 2. We found that pure turmeric powder had the highest curcumin concentration, averaging 3.14% by weight. The curry powder samples, with one exception, had relatively small amounts of curcumin present, and the variability in content was great across products.

As shown in Tables 1 and 2, labels for the turmeric and curry powders identified several countries of origin: India, Pakistan, Japan, Taiwan, Jamaica, Sri Lanka, Canada, and the United States. Several samples were labeled and identified with local market vendors in the Southern California cities of Riverside, San Diego, and Los Angeles. Based on label details (Table 2), all turmeric powders, regardless of country where manufactured or processed, were described as containing turmeric powder only. We observed that the two turmeric powders with the highest percentage of curcumin per dry weight (3.14% and 2.46%) had label markings indicating that they were prepared or produced in or were a product of the United States. In the turmeric powders, the average curcumin content (percentage of the dry weight), was 1.51%, with the lowest at 0.58% and the highest at 3.14%. The difference between the lowest and the highest curcumin content in the analyzed turmeric powder was 5.4-fold.

In our analysis of the spices labeled as curry powders (Table 1), the powders with the highest percentage of curcumin, 0.58% and 0.53%, were identified as products of Canada and Japan, respectively. In the spices labeled as curry powder, the average curcumin content was 0.28%, with a range of 0.05% to 0.58%. The difference between the lowest and highest curry powder blends was 11.6-fold. Turmeric, peppers, coriander, and fenugreek were the most commonly listed ingredients in the curry powders.

Two spices, listed in Table 2, were selected and measured originally as negative controls for curcumin, because these products would not be expected to contain curcumin. In the case of the Massala product, turmeric, curry, or curcumin

Table 1. Curcumin Content of Samples of Turmeric and Curry Powders

Spice Type	Identifying Number	Curcumin Mean (SD) (μg/mL)	Curcumin Content (percentage of dry weight)
Turmeric Powder	4	9.77 (0.058)	0.98
	8	5.77 (0.380)	0.58
	11	12.53 (0.058)	1.25
	20	10.42 (0.058)	1.04
	21	19.97 (0.054)	2.00
	24	31.37 (0.038)	3.14
	28	10.75 (0.050)	1.07
	29	10.46 (0.039)	1.05
	30	24.47 (0.014)	2.46
Curry Powder	1	5.33 (0.053)	0.53
	3	1.90 (0.000)	0.19
	5	3.50 (0.000)	0.35
	7	1.10 (0.000)	0.11
	9	0.50(0.000)	0.05
	10	3.13 (0.058)	0.31
	12	1.80 (0.000)	0.18
	13	1.00 (0.000)	0.10
	14	2.30 (0.000)	0.23
	15	1.10 (0.000)	0.11
	16	3.70 (0.100)	0.37
	17	1.10 (0.000)	0.11
	18	2.70 (0.000)	0.27
	19	2.73 (0.026)	0.27
	22	2.65 (0.019)	0.26
	23	4.96 (0.430)	0.49
	25	5.81 (0.150)	0.58
	26	4.11 (0.047)	0.41
	27	5.00 (0.000)	0.50

were not named in the ingredients listed in the label. However, a constituent eluted from the column with the chromatographic retention time consistent with curcumin, and it was noted that the label ingredients included the phrase "other spices." Thus, it is possible that turmeric or curry powder may have been included in that spice blend. In cardamon, a negative control, curcumin was not detected. The analytical drift as measured by the coefficient of variation in all but two instances was less than 3%. The analytical drift in two samples was less than 9%.

Discussion

Curcumin [1, 7-bis (4-hydroxy-3-methoxyphenyl)-1, 6-heptadiene-3, 5-dione] is the major yellow pigment extracted from turmeric, a commonly used spice, derived from the rhizome of the herb *curcuma longa Linn* (1,25). It is a naturally occurring polyphenolic phytochemical. There has been considerable public and scientific interest in the use of phytochemicals derived from the diet to reduce risk and progression of major chronic diseases (5), and turmeric has been used in Asian medicine since the 2nd millennium BC (5,26–27). In laboratory animal studies, curcumin, a major component of turmeric, has been shown to have the potential to contribute to the prevention of cancer and other chronic diseases due to various biological activities (25,28–32). In spite of suggestive laboratory evidence and current interest in a potential role for curcumin as a chemopreventive constituent of the diet, food content data for this compound are not available, and results of analysis of curcumin content of spices or foods are scarce.

Anecdotal evidence suggests that consumption of turmeric occurs on a daily basis in Indian and other Asian communities. In a review on the topic of curcumin, Sharma et al. (5) reported consumption of 1.5 g/person/day in certain Southeast Asian communities. However, no information was given as to the number sampled or the manner in which they were queried in that report. The regular consumption of turmeric has been suggested as a possible factor promoting the lower rate of cancer that has been observed in these communities when compared to cancer rates in countries such as the United States (18,33). However, without quantitative data that would allow disentangling the associations between curcumin intake and other influencing factors (including nondietary etiological factors), a cause and effect relationship cannot be assumed.

Thus, accurate information on the quantity of curcumin provided by turmeric and curry powders or other sources of curcumin in the diet would be useful to more accurately assess the intake of curcumin and to better examine possible chemopreventive effects. It has been reported by Sharma et al. (5) that over 2,400 metric tons of turmeric is imported annually into the United States for consumer use, which sug-

Table 2. Product Identification Information

ID	Name	Ingredients	Brand or Manufacturer
1	Sand B Oriental Curry Powder	Turmeric, coriander, fenugreek, cumin, red pepper, black pepper, cinnamon, ginger, star anise, cloves, cardamon, fennel, nutmeg, laurel leaves, allspice, garlic	S&B Foods Inc., Tokyo 103-0026, Japan; Product of Japan; Use in lamb, beef, chicken, shrimp, fish, fried rice and egg dishes
2	Cardamon Powder Bubuk Kapollaga	BOT Cardamon	Jara Brand; Packed for WIRA Corp., 168 Mason Way Unit A-6, CA 91746. USA
3	Curry Power India	Coriander, turmeric, cumin, other spices	TOMAX ENTERPRISE Co., Ltd., No.1 Industrial South 6th Rd., Natou City, Taiwan
4	Sadaf Powder Turmeric "Curcuma En Polvo"	Turmeric comes from the dried roots of curcuma longa spice plant, grows in India and China	Sadaf Brand, Soofer Co., Inc., Los Angeles, CA 90058; www.sadaf.com
5	Tampico Curry Powder	Spices, turmeric, salt, red pepper	Tampico Spice Co., Inc. 5941 So. Central Ave., Los Angeles, CA 90001
6	Sadaf Seasoning Garam Massala	Coriander, black pepper, cinnamon, rock salt, cardamon, other spices	Sadaf Brand, Soofer Co., Inc., Los Angeles, CA 90058; www.sadaf.com
7	Sadaf Hot Curry Powder	Chillies, black pepper, cayenne, fenugreek, curry leaves, ginger, turmeric	Sadaf Brand, Soofer Co., Inc., Los Angeles, CA 90058; www.sadaf.com
8	AHMED Turmeric Powder	Turmeric powder	AHMED Food International, 11-24, Sector C-111, K.E.P.Z., Karachi 75150; Product of Pakistan
9	AHMED Curry Powder (seasoning mix for meat/vegetable curry)	Red chilli, coriander, turmeric, black pepper, ginger, salt, cinnamon, cumin seeds, cardamon, mace, garlic (fresh buds), bay leaves, onion	AHMED Food International, 11-24, Sector C-111, K.E.P.Z., Karachi 75150; Product of Pakistan
10	Day Street Market Fresh Fruits and Vegetables Curry Powder Curry Molido	Not listed	Halal Meats Grocery and Produce, 12125 Day St. Suite F-301, Moreno Valley, CA 92557, Tel: (909) 682 3536
11	Day Street Market Fresh Fruits and Vegetables Turmeric	Turmeric powder	Halal Meats Grocery and Produce, 12125 Day St. Suite F-301, Moreno Valley, CA 92557, Tel: (909) 682 3536
12	Blue Mountain Jamaican Curry Powder	Coriander, cumin, fenugreek, turmeric, anise, red pepper	Blue Mountain Jamspice
13	Hot Curry Powder	Coriander, turmeric, salt, fennel, chilli, cumin, fenugreek, garlic, cassia, cloves, anise, pepper, cassia buds, curry leaves	Laxmi Brand; Product of India
14	Rani (mild curry powder)	Chilli, coriander, cumin, mustard, fenugreek, black pepper, curry leaves, ginger turmeric	Rani Brand; California
15	Green Label-Madras Curry Powder H.E. The Gov. of Bombay	Coriander, turmeric, salt, fennel, chilli, black pepper, fenugreek, garlic, cumin, bay leaves, ginger, cassia	Ship Brand
16	Larich Roasted Curry Powder	Coriander, fennel, cumin, fenugreek, cinnamon, nutmeg, cardamom, cloves, curry leaves	Larich Brand; Product of Sri Lanka
17	Rajah Brand Hot Madras Curry Powder	Coriander, turmeric, mustard, chilli, bengal gram, cumin, fenugreek, pepper, garlic, salt, fennel, poppy seeds, curry leaves	Rajah Brand
18	Schilling Indian Curry Powder (mild)	Coriander, fenugreek, turmeric, cumin, black pepper, bay leaves, celery seeds, nutmeg, cloves, onion, red pepper	Schilling Brand
19	Madrecita Curry Powder	Not listed	Madrecita 8280, Clairemont Mesa Blvd Suite 140, San Diego, CA, 92111
20	Madrecita Turmeric	Curcuma longa, ground turmeric	Madrecita 8280, Calrimont Mesa Blvd Suite 140, San Diego, CA 92111
21	Flower Brand Turmeric Powder HALDI	Turmeric powder	Flower Brand MK Agro Exports Mumbai-India, SAHA Distributors, Tel: (310) 719 1011 Fax: (310) 719 1112; Product of India
22	Flower Brand Curry Powder Hot (mixed spices)	Coriander, fenugreek, turmeric, cumin, chilli, mustard, other spices	Flower Brand MK Agro Exports Mumbai-India, SAHA Distributors, Tel: (310) 719 1011 Fax: (310) 719 1112; Product of India

(continued)

Table 2. *Continued*

ID	Name	Ingredients	Brand or Manufacturer
23	Tone's Curry Powder	Spices, turmeric, salt, red pepper, spice extractive	Tone Brothers, Inc., Ankeny, IA 50021, USA; www.tones.com
24	Tone's Ground Turmeric	Turmeric powder	Tone Brothers, Inc., Ankeny, IA 50021, USA; www.tones.com
25	Spice Box Curry Powder	Spices, wheat flour, salt, garlic powder, silicon dioxide	ENCORE Gourmet Food Corp., Montreal QC Canada H9X 4B4; Product of Canada
26	Spice Supreme Curry Powder	Mustard, turmeric, coriander, cumin, cloves	Gel Spice Co., Inc., Bayonne, NJ 07002; Made in USA
27	EL GUAPO Curry Powder	Coriander, fenugreek, turmeric, cumin, black pepper, bay leaves, celery seeds, nutmeg, cloves, onion, red pepper, ginger	EL GUAPO, 6200 E. Slauson Ave., Los Angeles, CA, 90040
28	Golchin Turmeric Powder	Turmeric powder	Overseas Food Dist. Inc., Sylmar, CA 91342; Tel: (818) 896 6127
29	Mahran Turmeric Powder	Turmeric powder	Pure Food Limited, P.O. Box 16872, Jabel Ali Free Zone, Tel: 009714 8816848, Fax: 009714 8816134, Dubai/UAE; Processed in UAE; Product of Pakistan
30	McCormick Ground Turmeric	Turmeric powder	McCormick and Co. Inc., P.O. Box 208, Hunt Valley MD 21030-0208; Packed in USA

gests that the amount of curcumin consumed could have biological effects depending on food choices and use of curcumin-containing spices.

Clinical trials are currently examining the pharmacokinetic properties and effects of curcumin supplementation on various biological activities that are relevant to the risk and progression of cancer (34). Knowledge of curcumin intake from the diet and food choices would be useful in designing and interpreting the results of the response in these studies. For example, higher tissue concentrations and exposure at baseline would be useful in interpreting the response to supplementation. The wide variation in curcumin content of the several brands of turmeric and curry powders that was observed in this study suggests that considerable variability in tissue concentration could exist across subjects and groups involved in these studies.

Conclusions

Curcumin content of turmeric and curry powders is highly variable. Pure turmeric powder has the highest curcumin concentration, and relatively small amounts of curcumin are present in curry powder samples. As a first step toward quantifying curcumin intake from the diet, these data contribute to knowledge that would be useful in the interpretation of findings relating curcumin intake to cancer risk and prevention and to the response to curcumin supplementation in pharmacokinetic studies and chemoprevention trials.

Acknowledgments and Notes

The first author would like to acknowledge the L'OREAL-UNESCO organization for the Women in Science Award Scholarship, which provided some funding for this project. We also thank Fatima Khwaja for her important contributions to this project. This project was completed at the University of California, San Diego, in La Jolla, CA. Address correspondence to D. Heath, MS, UCSD Cancer Prevention and Control Program, 3855 Health Sciences Drive, Dept. 0803, La Jolla, CA 92093-0803. Phone: 858–822–1123. FAX: 858–822–1497. E-mail: dheath@ucsd.edu.

Submitted 10 May 2006; accepted in final form 24 May 2006.

References

1. Ireson CR, Jones DJL, Orr S, Coughtrie MWH, Boocock DJ, et al.: Metabolism of the cancer chemopreventive agent curcumin in human and rat intestine. *Cancer Epidemiol Biomarkers Prev* **11,** 105–111, 2002.
2. Chen CM and Fang HC: Chemical analysis of the active principles of Curcuma species. In: *Modern Treatise on Chinese Herbal Medicines, Vol. III.* Sung CY, Chou DW, Fung CJ, and Zhao HM (eds). Beijing, PRC: Institute of Pharmaceutical Sciences, Medical Academia, 1997, pp 95–105.
3. Holt PR, Katz S, and Kirshoff R: Curcumin therapy in inflammatory bowel disease: a pilot study. *Dig Dis Sci* **50,** 2191–2193, 2005.
4. Shishodia S, Sethi G, and Aggarwal BB: Curcumin: getting back to the roots. *Ann N Y Acad Sci* **1056,** 206–217, 2005.
5. Sharma RA, Gescher AJ, and Steward WP: Curcumin: the story so far. *Eur J Cancer* **41,** 1955–1968, 2005.
6. Chainani-Wu N: Safety and anti-inflammatory activity of curcumin: a component of tumeric (Curcuma longa). *J Altern Complement Med* **9,** 161–168, 2003.
7. Iqbal M, Sharma SD, Okazaki Y, Fujisawa M, and Okada S: Dietary supplementation of curcumin enhances antioxidant and phase II metabolizing enzymes in ddY male mice: possible role in protection against chemical carcinogenesis and toxicity. *Pharmacol Toxicol* **92,** 33–38, 2003.
8. Kuo ML, Huang TS, and Lin JK: Curcumin, an antioxidant and anti-tumor promoter, induced apoptosis in human leukemia cells. *Biochim Biophys Acta* **1317,** 95–100, 1996.
9. Sreejayan A: Curcuminoids as potent inhibitors of lipid peroxidation. *J Pharm Pharmacol* **46,** 1013–1016, 1994.
10. Subramanian M, Sreejayan A, Devasagyam A, and Singh B: Diminution of singlet oxygen-induced DNA-damage by curcumin and related antioxidants. *Mutat Res* **311,** 249–255, 1994.

11. Ramirez-Tortosa MC, Mesa MD, Aguilera MC, Quiles JL, Baro L, et al.: Oral administration of a turmeric extract inhibits LDL oxidation and has hypocholesterolemic effects in rabbits with experimental atherosclerosis. *Atherosclerosis* **147,** 371–378, 1999.
12. Babu PS and Srinivasan K: Hypolipidemic action of curcumin, the active principle of turmeric (Curcuma longa) in streptozotocin induced diabetic rats. *Mol Cell Biochem* 1**66,** 169–175, 1997.
13. Soni KB and Kuttan R: Effect of oral curcumin administration on serum peroxides and cholesterol levels in human volunteers. *Indian J Physiol Pharmacol* **36,** 273–275, 1992.
14. Duvoix A, Blasius R, Delhalle S, Schnekenburger M, Morceau F, et al.: Chemopreventive and therapeutic effects of curcumin. *Cancer Lett* **223,** 181–190, 2005.
15. Garcea G, Berry DP, Jones DJ, Singh R, Dennison AR, et al.: Consumption of the putative chemopreventive agent curcumin by cancer patients: assessment of curcumin levels in the colorectum and their pharmacodynamic consequences. *Cancer Epidemiol Biomarkers Prev* **14,** 120–125, 2005.
16. Leu TH and Maa MC: The molecular mechanisms for the antitumorigenic effect of curcumin. *Curr Med Chem Anti-Canc Agents* **2,** 357–370, 2002.
17. Busquets S, Carbo N, Almendro V, Quiles M.T, Lopez-Soriano FJ, et al.: Curcumin, a natural product present in turmeric, decreases tumor growth but does not behave as an anticachectic compound in a rat model. *Cancer Lett* **167,** 33–38, 2001.
18. Chauhan DP: Chemotherapeutic potential of Curcumin for colorectal cancer. *Curr Pharm Des* **8,** 1695–1706, 2002.
19. Garcea G, Jones DJL, Singh R, Dennison AR, Farmer PB, et al.: Detection of curcumin and its metabolites in hepatic tissue and portal blood of patients following oral administration. *Brit J Cancer* **90,** 1011–1015, 2004.
20. Ravindranath V and Chandrasekhara N: Absorption and tissue distribution of curcumin in rats. *Toxicology* **16,** 259–265, 1980.
21. Cheng AL, Hsu CH, Lin JK, Hsu MM, Ho YF, et al.: Phase I clinical trial of curcumin, a chemopreventive agent, in patients with high-risk or premalignant lesions. *Anticancer Res* **21,** 2895–2900, 2001.
22. Jayaprakasha GK, Rao LJM, and Sakariah KK: Improved HPLC Method for the determination of curcumin, demethoxycurcumin, and bisdemethoxycurcumin. *J Agric Food Chem* **50,** 3672–3668, 2002.
23. Hossain MA and Ishimine Y: Growth, yield and quality of turmeric (Curcuma longa L.) cultivated on dark-red soil, gray soil and red soil in Okinawa, Japan. *Plant Production Sci* **8,** 482–486, 2005.
24. Sasikumar B: Genetics resources of Curcuma: diversity, characterization and utilization. *Plant Genetic Resources Characterization Util* **3,** 230–251, 2005.
25. Heath DD, Pruitt MP, Brenner DE, and Rock CL: Curcumin in plasma and urine: quantitation by high-performance liquid chromatography. *J Chromatography B* **783,** 287–295, 2003.
26. Brouk B: *Plants consumed by man.* New York: Academic Press, 1975, p 331.
27. Majeed M, Babmaev V, Shivakumar R, Rajendran R: *Turmeric and the Healing Curcuminoids.* Piscataway, NJ: Nutriscience Press, 1995, p.9.
28. Shao Z-M, Shen Z-Z, Liu C-L, Sartippour MR, Go VL, et al.: Curcumin exerts multiple suppressive effects on human breast carcinoma cells. *Int J Cancer* **98,** 234–240, 2002.
29. Anto RJ, Mukhopadhyaya A, Denning K, and Aggarwal BB: Curcumin (diferuloylmethane) induces apoptosis through activation of caspase-8, BID cleavage and cytochrome c release: its suppression by ectopic expression of Bcl-2 and Bcl-xl. *Carcinogenesis* **23,** 143–150, 2002.
30. Rao CV, Rivenson A, Simi B, and Reddy BS: Chemoprevention of colon carcinogenesis by dietary curcumin, a naturally occurring plant phenolic compound. *Cancer Res* **55,** 259–266, 1995.
31. Huang MT, Lou YR, Ma W, Newmark HL, Reuhl KR, et al.: Inhibitory effects of dietary cuecumin on forestomach, duodenal, and colon carcinogenesis in mice. *Cancer Res* **54,** 5841–58417, 1994.
32. Shukla Y, Arora A, and Taneja P: Antimutagenic potential of curcumin on chromosomal aberrations in Wistar rats. *Mutation Res* **515,** 197–202, 2002.
33. Sinha R, Anderson DE, McDonald SS, and Greenwald P: Cancer risk and diet in India. *J Postgrad Med* **49,** 222–228, 2003.
34. Lao CR, Ruffin IV MT, Normolle D, Heath DD, Murray SI, et al.: Dose escalation of a curcuminoid formulation. *BMC Complementary Alternative Med* **6,** 10–13, 2006.