EFFECT OF INHERENT ANTIOXIDANT PROPERTY ON HOME STORAGE OF WHEAT AND TURMERIC FLOURS

Sumita Bagchi[2], Amitava Chatterjee[1*], Pravas Das[1], Sonali Ghosh[2], Kamala Adak[2]
[1]W.B.P.H.L., Dept. of Health & F.W., Govt. of West Bengal, 2, Covent Lane, Kolkata-700 015, West Bengal, India.
[2]Dept. of Home Science, University of Calcutta, 20B, Judges Court Road, Kolkata-700 027, West Bengal, India.
[1*]W.B.P.H.L., Dept. of Health & F.W., Govt. of West Bengal, 2, Covent Lane, Kolkata-700 015, West Bengal, India
*E-mail: amitavachatterjee.phl@rediffmail.com

Abstract
The study aims to evaluate the effect of home storage (stored in normal kitchen containers for 1 month) on the physico-chemical properties of both packaged and stone grinded turmeric powder, Curcuma longa L and whole wheat flour. The samples were analyzed with respect to moisture, starch, and curcumin contents for turmeric powder and moisture, gluten and starch contents for whole wheat flour at an interval of 10 days. During the experimental period, an almost twice the degradation of starch content of wheat than in turmeric powder, loss of gluten content by 23.6% (packaged); 26.9% (stone grinded) of wheat, decrease in curcumin content by 33.07% (stone grinded); 33.69% (packaged) – all indicate increased protein & starch hydrolysis in wheat; being attributed to the preservative action of antioxidant curcumin, which is present in turmeric and absent in wheat flour. The present study suggested stone grinded turmeric rhizome and wheat flours as nutritionally better food items. From the study a new avenue may be opened up by mixing the potent, natural and easily available antioxidant - curcumin (from turmeric) with various raw and perishable and semi-perishable food materials, which need storage at home or otherwise to extend their shelf life resulting in retaining the nutritional quality.

Key words: turmeric, curcumin, wheat, gluten, starch, antioxidant property, moisture, nutritional quality.

Submitted: 14.04.2015 Reviewed: 08.06.2015 Accepted: 18.06.2015

1. INTRODUCTION

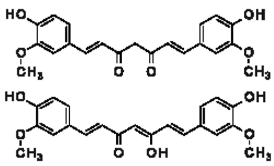
The modern food industry has developed and expanded because of its ability to deliver a wide variety of high quality food products to the consumers on a nationwide and worldwide basis. This feat has been accomplished by building stability into the products through processing, packaging, and additives that enable foods to remain fresh and wholesome throughout the distribution process. Shelf life of food can be defined as the recommendation of time that products can be stored, during which the defined quality of a specified proportion of the food remains acceptable under expected (or specified) conditions of distribution, storage and display. Many factors influence shelf-life of food products. The shelf-life of food products is dependent on the interactive effects of intrinsic parameters (e.g. pH, water activity) and extrinsic parameters (e.g. storage temperature, humidity level and gaseous environment), as well as the raw material quality and sanitary conditions applied during manufacturing. Microbiological and chemical changes and physical deterioration during storage determine the shelf-life of a product. Microbiological changes occur as a result of microbiological growth of indigenous microflora. Chemical changes occur as a result of chemical reactions such as enzymatic degradation, non-enzymatic reactions and oxidation. A well-designed shelf-life study provides vital information on the microbiological, chemical and organoleptic changes in a product formulation during product storage. A number of variables must be considered when designing a shelf-life study. Storage temperature, relative humidity, types of analyses (i.e. microbiological, chemical or

© 2015 Valahia University Press
Further reproduction without permission is prohibited

organoleptic analyses), method of analyses, sampling method, and number of replications and duration of the study are some of these variables. In our study, we have chosen a semi-perishable food product (whole wheat flour) and a less-perishable spice (turmeric) in order to find out the impact of different ambient factors on the nutritionally acceptable quality of them.

Curcumin

Fresh turmeric powder contains up to 5% curcumin, a polyphenol. Curcumin is the active substance of turmeric and curcumin is known as C.I. 75300, or Natural Yellow 3. The systematic chemical name is **(1*E*,6*E*)-1,7-bis(4-hydroxy-3-methoxyphenyl)-1,6-heptadiene-3,5-dione.** It was first isolated from the drug in 1815, but its structure was not elucidated until 1913. The structure was first identified by Miłobędzka, J. *et al.,* (1910). Curcumin is insoluble in water, but soluble in ethanol and acetone. The naturally occurring ratios of curcuminoids in curcumin are about 5% bisdemethoxycurcumin, 15% demethoxycurcumin, and 80% Curcumin (Ireson *et al*., 2001 & Ireson *et al*., 2002).



Curcumin (enol form) Curcumin (keto form)

Chemistry

Curcumin incorporates several functional groups. The aromatic ring systems, which are phenols, are connected by two α, β-unsaturated carbonyl groups. It can exist at least in two tautomeric forms, keto and enol. The keto form is preferred in solid phase and the enol form in solution. Curcumin is a pH indicator. In acidic solutions (pH<7.4) it turns yellow, whereas in basic (pH > 8.6) solutions it turns bright red. The diketones form stable enols and are readily deprotonated to form enolates; α, β-unsaturated carbonyl group is a good Michael acceptor and undergoes nucleophilic addition.

Pharmacological properties of curcumin
Antioxidant property

Curcumin is known to protect biomembranes against peroxidative damage. Peroxidation of lipids is known to be a free-radical-mediated chain reaction, leading to the damage of the cell membranes, and the inhibition of per oxidation by curcumin is mainly attributed to the scavenging of the reactive free radicals involved in the peroxidation. Most of the antioxidants have either a phenolic functional group or a diketone group. Curcumin is an unique antioxidant, which contains a variety of functional groups, including the β-diketo group, carbon–carbon double bonds, and phenyl rings containing varying amounts of hydroxyl and methoxysubstituents.

The central argument is whether the phenolic or the central methylenic hydrogen in the heptadienone moiety is responsible for its antioxidant activity. Jovanovic and collaborators (1999) concluded that curcumin is a superb H-atom donor by donating the H-atom from the central methylenic group rather than from the phenolic group in acidic and neutral aqueous and acetonitrile solutions. On the other hand, Barclay *et al*., (2000) proposed that curcumin is a classical phenolic chain-breaking antioxidant, donating H-atoms from the phenolic group. Priyadarsini *et al*., (2003) have also claimed that the phenolic group is essential for the free-radical-scavenging activity and that the presence of the methoxy group further increased the activity.

The antioxidant property of Curcumin and its three derivatives are studied by Unnikrishnan and Rao, (1995). The authors demonstrated that the use of Curcumin provides the protection of hemoglobin from oxidation at very low concentration as 0.08 mM.

Curcumin has been found to be ten times more active than vitamin E. In Curcumin, the phenolic and methoxy group on the phenyl ring and the 1.3-diketone system seem to be important structural features that can contribute to the antioxidant property of the Curcumin (Motterlini *et al*., 2000).

Turmeric's other two curcuminoids are desmethoxycurcumin and bisdesmethoxycurcumin. The curcuminoids are natural phenols that are responsible for the yellow color of turmeric but without residual turmeric flavor. It is obtained by curcumin extraction from turmeric powder with solvent followed by washing and purification of curcumin by precipitation or crystallization (Govindrajan, 1980). Recently, it has been valued worldwide as a functional food, due to its health promoting properties.

Turmeric has been used as an antioxidant, digestive, anti-microbial, anti-inflammatory and anti-carcinogenic agent. It lowers total cholesterol levels. It is also efficient in the treatment of circulatory problems, liver diseases, dermatological disorders and in blood purification (Krishnamurthy *et al*. 1975, Krishnamurthy *et a*. 1976, Semwal *et al*. 1997, Osawa *et al*. 1995, Guimarães, 1987, Srinivas *et al*. 2008, Srinivasan *et al*. 1992, Hallagan *et al*. 1995).

Thus, the two most commonly used raw food materials (used in this subcontinent) with diversifying characteristics w.r.t. inherent antioxidant property, have been selected for the study, to see how far the inherent shielding effect of antioxidant is responsible towards arresting degradation during normal storage conditions.

Hence, study objectives are:

- To analyse the raw food products (whole wheat and turmeric) under normal storage condition with respect to their principal constituents.
- To compare the quality of different variety of whole wheat flour and turmeric i.e. packaged & stone grinded with reference to the loss of the principal constituents.
- To analyse the antioxidant property of curcumin (present in turmeric) towards lessening of overall degradation of turmeric w.r.t. wheat.

2. MATERIAL AND METHODS

Instruments & apparatus: Toluene distillation apparatus, Reflux condenser and Hot-air oven, HPLC (Agilent 100 series).

Reagents & Chemicals: Packaged Turmeric powder &Whole wheat flour as well as raw turmeric rhizome & wheat grains were purchased from local market. All the reagents and chemicals and Curcumin standard had been procured from Merck and/or Ranbaxy Labs.

Estimation of moisture content:-

Turmeric: Estimated by Dean & Stark moisture distillation method. (AOAC manual & methods 986.21) (AOAC 17th Edi 2000, IS specification No. IS 1797).

Wheat flour: Estimated by following Ref: IS 4333 (Part II): 1967 Methods of Analysis of Food Grains Part II Moisture (IS 4333, Part II).

Estimation of starch content:-

Turmeric: Estimated titrimetrically by Lane & Eynon volumetric method using Fehling's solution & methylene blue as an internal indicator (I.S. specification No. IS 3576-1994) (Lane *et al*. 1994, Lane *et al*. 1923).

Wheat Flour: Estimated by following I.S. Specification No. 2446-1980 (I.S. Specification No. 2446-1980).

Estimation of curcumin content:-

Standard curve preparation:

Curcumin standard and CH_3CN, Methanol, Acetic Acid (2%), all HPLC grade, were used to prepare the standard curve and measured at 425 nm in HPLC using C18 column, flow rate of 0.8ml/min (Guddadarangavvanahally *et al*. 2002).

Curcumin content of sample:

After refluxing with 95% alcohol, extract was transferred quantitatively vol. flask and volume made up with alcohol and diluted for measurement in HPLC against standard curcumin solution. Column: C18; flow rate: 1ml/min.; temperature: ambient; solvent:

CH_3CN, Methanol, Acetic Acid (2%); Absorbance: 425nm (Guddadarangavvanahally *et al*. 2002).

Estimation of Gluten content:

Estimated by following Method Ref: IS 1155: 1968 Specification for Wheat Atta/ ISI Handbook of Food Analysis (part IV) Page 115 (ISI Handbook of Food Analysis, 1968).

3. RESULTS AND DISCUTION

Moisture

From the results (Table 1) it is observed that moisture content of wheat and turmeric increases with time. This is because the air within the container makes the food products moist since the components of food products absorb water and swell. Every time, the container is opened some air gets entered which is responsible for increasing the level of moisture in food products. Increase in moisture content increases the chances of microbial spoilage due to the increase in water activity (a_w) and thus results in deterioration of food quality. Storage temperature, relative humidity are important variables under consideration and as normal home storage is done these two variables are supposed to be the external variables. The increase in moisture level with time thus generally indicates the deterioration of quality for most of the food products. The qualities of wheat products are generally dependent upon the moisture content. With excess moisture their keeping qualities are impaired and become rapidly stale, lumpy and infested with insects. The higher percentage of protein, fat and salts in wheat favour the insect damage in presence of moisture as it is devoid of any antimicrobial or antioxidant properties which can help against any enzymatic/oxidative decay. In case of turmeric, the decay due to microbial growth is arrested as because a principle component of turmeric i.e. curcuminoids which exerts anti-oxidant property and hinders the breakdown due to microbial action.

Starch

The starch content is generally higher in wheat (~66-68%) than in turmeric (~55-59%) **(Table1)**. Starch was observed to be the major component of turmeric with an average of 40% of the dry matter. According to Mangalakumari & Mathew, 1986 and Tonnesen *et al*. 1985, turmeric is relatively rich in starch. Starch content of turmeric decreases with time as enzymatic decaying is responsible for breakdown of starch to simple sugars.

Table1: Loss of principal constituents of wheat and turmeric flours on storage

Parameter	Day	Wheat						Turmeric					
		Pkd€	L/G¥ (%)	Overall L/G	H/G£	L/G¥ (%)	Overall L/G	Pkd€	L/G¥ (%)	Overall L/G	H/G£	L/G¥ (%)	Overall L/G
	1	9.20	--		8.86	--		8.29	--		9.50	--	
Moisture	10	10.50	14.13		10.67	16.96		9.57	15.44		10.54	10.95	
(%)	20	11.55	10.00	23.40	12.02	12.65	29.18	10.21	6.69	22.60	10.85	2.94	13.71
	30	12.01	3.98		12.51	4.08		10.71	4.90		11.01	1.47	
	1	67.77	--		66.22	--		59.32	--		55.79	--	
Starch	10	66.11	2.45		64.55	2.52		58.64	1.15		54.76	1.85	
(%)	20	64.42	2.56	8.26	62.23	3.59	9.69	57.71	1.59	4.38	53.55	2.21	6.52
	30	62.17	3.49		59.80	3.90		56.72	1.71		52.15	2.61	
	1	12.30	--		13.10	--		--			--		
Gluten	10	12.27	0.24		12.36	5.65		--			--		
(%)	20	11.33	7.66	12.20	10.79	12.70	28.24	--			--		
	30	9.20	18.80		9.40	12.88		--			--		
	1	--			--			3.77	--		3.84	--	
Curcumin	10	--			--			3.65	3.18		2.98	22.40	
(%)	20	--			--			2.85	21.92	33.69	2.94	1.34	33.07
	30	--			--			2.50	12.28		2.57	12.59	

€: Packaged; £: Hand Grinded; ¥: Loss/Gain;

Starch content is highest in packaged powder (59.32%) followed by hand grinded dried rhizome (55.79%) turmeric powder. The decrease in starch content in wheat is more than that in turmeric. This difference in decrement of starch content due to home storage between the two products may be attributed to the antioxidant property of curcumin (present in turmeric) acting as a shielding effect, which is absent in wheat flour.

Gluten

Gluten content is another parameter which gives the idea of storage quality of wheat flour. Gliadin and glutelins are known as "gluten" proteins and they form with salt and water, the substance gluten when flour water dough is kneaded. Glutelin gives toughness or rubberiness, whereas, gliadin adds elasticity to the gluten protein. During the mixing of dough the long strands of glutelin evidently become aligned in the direction of mixing and associated with gliadin molecules to form a strong elastic uniform film that envelops the starch granules in the dough. On storage, the gluten protein undergoes enzymatic degradation leading to the breakage of disulphide bond(S-S). Substantial hydrolysis of gliadin and glutelin proteins occurs during dough fermentation; proteolysis in dough and the rheological consequences of gluten degradation are mainly based on the pH-mediated activation of cereal enzymes. This makes the gluten protein slippery on storage and the loss of gluten content reveals the loss of quality, which is evident from the data **(Table1)**. Overall loss of gluten content on storage ranged from 12.20% (packaged) to 28.24% (stone grinded) which are proportional to the percentage increase of moisture during this period of storage, viz. 23.40% (packaged) and 29.18% (stone grinded), indicative of increased protein hydrolysis with increase in moisture holding. Gluten content of stone grinded flour has been found to be the highest (13.10%) followed by packaged flour (12.30%), which reveals that some protein in the form of gluten might have been lost in the process of pulverization, milling and other processing of whole wheat.

Curcumin content

In case of turmeric, storage time exerts significant impact on the curcumin content (Tonnesen *et al*. 1985, Showbagya *et al*. 2005). Curcumin is the principal curcuminoid of the popular Indian spice turmeric. The antioxidant property of curcumin (Semwal *et al*. 1997, Osawa *et al*. 1995) can prevent rancidity of foods and provide foodstuffs containing less oxidized fat or free radicals. Previous studies have demonstrated the sensibility of curcuminoid pigments to oxygen, light and alkaline pH (Krishnamurthy *et al*. 1976, Govindarajan, 1980) the stability of curcuminoid pigments, was not affected by water activity (a_w). Therefore, the change in moisture content with time would not affect pigment stability. Curcumin is sensitive to light but is moderately stable to heat (Krishnamurthy *et al*. 1975, Krishnamurthy *et al*. 1976, Semwal *et al*. 1997, Osawa *et al*. 1995). However, during long term storage of ground turmeric, a better quality packing material should be used. Variation in curcuminoid pigment levels can be related to diversity in cultivars and varieties, location, agricultural practices, use of fertilizers and degree of maturity (Osawa *et al*. 1995, Guimarães, 1987). On storage, curcumin content decreases but to a little extent which indicates its photosensitive nature. Curcumin content is highest in hand grinded dried fresh rhizome powder (3.84%) followed by packaged turmeric powder (3.77%). The average decrease in curcumin content ranged from 33.07% (stone grinded) to 33.69% (packaged) within 30 days of ambient temperature storage, indicating a lesser dependence on the water activity of the sample.

4. CONCLUSIONS

Henceforth, from the light of the study it can be concluded that-

1. Hand grinded dried rhizome powder is the best quality turmeric powder because of its rich

content of curcumin and quite fair source of starch followed by branded turmeric powder.
2. On storage period of 1month, turmeric powder loses its quality in terms of its flavour and aroma and chemical changes including raised enzymatic activity, high water activity and photosensitivity cause degradation of its quality.
3. Hand grinded wheat flour is of the best quality wheat flour in terms of gluten protein followed by branded one.
4. The average decrease in curcumin content ranged from 33.07% (stone grinded) to 33.69% (branded) within 30 days of ambient temperature home storage.
5. The decrease in starch content with respect to wheat is almost double than in turmeric.
6. Loss of gluten content on storage ranged from 12.20% (packaged) and 28.24% (stone grind), indicative of increased protein hydrolysis with increase in moisture holding.
From the study a new avenue may be opened up by mixing the potent, natural and easily available antioxidant - curcumin (from turmeric) with various raw and perishable and semiperishable food materials which need storage at home or otherwise to extend their shelf life resulting in retaining the nutritional quality.

5. ACKNOWLEDGEMENTS

Research conducted with contributions from the Dept. of Home Science, University of Calcutta, West Bengal, India, for funding and infrastructural support and WBPHL, Dept. of Health & F.W. Govt. of West Bengal, India for infrastructural and technical support.
The authors also are indebted to Dr. Sumana Ghosh, Dept. of Chemistry, HMM College for Women, Kolkata, India, for valuable suggestions.

6. REFERENCES

[1] Miłobędzka, J., S.T.V. Kostanecki, V. Lampe,: Zur Kenntnis des Curcumins. *Berichte der deutschen chemischen Gesellschaft,* 1910, **43**, 2, 2163–2170.
[2] Ireson, C, Orr, S, Jones, D.J., Verschoyle, R, Lim, C.K., Luo, J.L., Howells, L, Plummer, S, Jukes, R, Williams, M, Steward, W.P., Gescher, A: Characterization of metabolites of the chemopreventive agent curcumin in human and rat hepatocytes and in the rat in vivo, and evaluation of their ability to inhibit phorbol ester-induced prostaglandin E2 production. *Cancer Res*., 2001, **61**, 3, 1058–1064. [PubMed]
[3] Ireson, C.R., Jones, D.J., Orr,S., Coughtrie, M.W., Boocock, D.J., Williams, M.L., Farmer, P.B., Steward, W.P., Gescher, A.J.: Metabolism of the cancer chemopreventive agent curcumin in human and rat intestine. Cancer Epidemiol, Biomarkers Prevention, *Am Assoc Cancer Res*, Am Soc Preventive Oncol., 2002,**11**,1,105–111.
[4] Jovanovic, S. V., Steenken, S. C., Boone, W., Simic, M. G.: H-atom transfer is a Preferred antioxidant mechanism of curcumin,.*J Am Chem Soc***,** 1999, **121**, 9677–9681.
[5] Barclay, L. R. C., Vinqvist, M. R., Mukai, K., Goto, H., Hashimoto, Y., Tokuanga, A.: The antioxidant mechanism of curcumin: Classical methods are needed to determine antioxidant mechanism and activity, *Org Lett,* 2000, **2**, 2841–2843.
[6] Priyadarsini, K. I., Maity, D. K., Naik, G. H., Kumar, M. S., Unnikrishnan, M. K., Satav, J.G., Mohan, H.: Role of phenolic OH and methylene hydrogen on the free radical reaction and antioxidant activity of curcumin Free Radical. *Biol Med***,** 2003, **35**, 475–484.
[7] Unnikrishnan, M.K., Rao, M.N.: Inhibition of nitrite induced oxidation of hemoglobin by curcuminoids. *Pharmazie,* 1995, **50**, 490-492.
[8] Motterlini, R., Foresti, R., Bassi, R., Green, C.J.: Curcumin, an antioxidant and antiinflammatory agent, induces heme oxygenase-1 and protects endothelial cells against oxidative stress. *Free Radic Biol Med*., 2000, **28**, 8, 1303–1312.
[9] Govindarjan, V.S.: Turmeric – chemistry, Technology, and Quality. *CRC Critical Review in Food Science and Nutrition*, 1980, **12**, 3, 199-301.
[10] Krishnamurthy, N., Padmabai, R., Natarajan, C.P., Kuppusnamy, S.: Colour content of turmeric varieties and studies on its processing. *J. Food Sci. Technol.,* 1975, **12**, 12-14.
[11] Krishnamurthy, N., Mathew, A.G., Nambudiri, E.S., Shivashankar, S., Lewis, Y.S., Natarajan, C.P.: Oil and oleoresin of turmeric. *Trop. Sci,*1976, **18**, 37-45.
[12] Semwal, A.D., Sharma, G.K., Arya, S.S.: Antioxygenic activity of turmeric (*Curcuma longa*) in sunflower oil and ghee. *J. Food Sci. Technol.,* 1997, **34**, 67-69.
[13] Osawa, T., Sugiyama, Y., Inayoshi, M., Kawakishi, S.: Antioxidative activity of tetrahydrocurcuminoids.*Biosci. Biotech. Biochem*., 1995, **59**, 1609-1612.
[14] Guimarães, I.S.S.: Corantes naturais vermelhos e amarelos. *Symposio sobre aditivos para alimentos*. Campinas ETA, 1987, pp.2.
[15] Srinivas, B.M.M., Mythri, R., Jagatha, B., Vali, S.: Neuroprotective effect of curcumin against inhibition of mitochondrial complex I in vitro and in

vivo.Implications for Parkinson's disease explained via in silico studies. J. Neurochem., 2008, **106**, 9–28.
[16] Srinivasan, K., Sambaiah, K., Chandrasekhara, N.: Loss of active principles of common spices during domestic cooking. *Food Chemistry*, 1992, **43**, 271-274.
[17] Hallagan, J.B., Allen, D.C., Borzelleca, J.F.: The safety and regulatory status of food, Drug and cosmetics colour additives exempt from certification. *Food Chemical Toxicology*, 1995, **33**, 6, 515-528.
[18] AOAC 17th Edi 2000 Official Method 986.21. Moisture in Spices / IS specification No. IS 1797-1985; Methods of Test for Spices & Condiments
[19] Moisture in Spices, *1985*, *IS specification No. IS 1797.*
[20] Methods of Analysis of Food Grains Part II Moisture, 1967, *IS 4333, Part II*.
[21] Lane, J.H., Eynon, L.: Volumetric method using Fehling's solution & methylene blue as an internal indicator, 1994, *I.S. specification No. IS 3576.*
[22] Lane, J.H., Eynon, L.: Determination of reducing sugars by means of Fehling's solution with methylene blue as internal indicator, 1923, *J. Soc. Chem*.
[23] Ind. Trans. 32-36.*I.S. Specification No. 2446-1980*.
[24] Guddadarangavvanahally, K.J., Lingamullu, J. M. R., Kunnumpurath, K.S.: Improved HPLC method for the determination of curcumin, demethoxycurcumin and bisdemethoxycurcumin. *J. Agric. Food Chem*., 2002, **50**, 13, 3668-3672.
[25] Specification for Wheat Atta, IS 1155, *ISI Handbook of Food Analysis,* part IV*,* 1968, Page 115.
[26] Mangalakumari, C.K., Mathew, A.G.: Localization of significant constituents of turmeric. *J. Food Sci. Technol.*, 1986, **23**, 93-96.
[27] Tonnesen, H.H., Karlsen, J.: Studies on Curcumin and Curcuminoids. Kinetics of Curcumin Degradation in Aqueous-Solution. *Z. Lebensm. Unters. For*., 1985, **180,** 402–404. [PubMed]
[28] Tonnesen, H.H., Karlsen, J.: Studies on Curcumin and Curcuminoids. Alkaline-Degradation of Curcumin. *Z. Lebensm. Unters. For*., 1985, **180,** 132–134.
[29] Showbagya, H.B., Smitha, S., Sampathu, S.R., Krishnamurthy, N., Battacharya, S.: Stability of watersoluble turmeric colorant in an extruded food product during storage. *Journal of Food Engineering*, 2005, **67,** 3, 367-371.
[30] Govindarajan, V.S.: Turmeric - chemistry, technology and quality. *Crit. Rev. Food Sci. Nutr*., 1980, **12**, 199-205.