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Curcuma longa: AReview on Its Bioprospecting

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Abstract: *Curcuma longa or turmeric, belongs to family Zingiberaceae, has many beneficial properties to be discovered for bioprospecting. The rhizome that consists of primary and secondary metabolites i.e carbohydrates, protein, saponin, tannin, flavonoid (includes curcumin), phenol, and sterol makes turmeric acceptable and extremely valuable for human consumption, drugs and natural colorant industry, and animal additional feed. Turmeric also provides biological activity such as antioxidant, anti-inflammatory, anti-bacterial, anti-cancer, and anti-HIV especially in dealing with human diseases through some mechanism of actions. In addition, turmeric plays role as a growth promotor, health protector, and quality and quantity product improver for livestock, while in fishery it acts as growth promotor, anti-bacterial, and color improver for ornamental fish. Those advantageous benefit demonstrate C. longa as a promising medicinal plant for further product development based on industrial purporse, particularly that comes from curcumin.*

Keywords: *biological activity, bioprospecting, Curcuma longa, fishery, livestock, phytoconstituent, turmeric*

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I. Introduction

Curcuma longa or turmerichas many utilizations for food, pharmaceutical industry, and animal. Ithas been widely used in India, China, and South East Asia as a spice, food preservative and coloring material[1]. Turmeric traditionally involved in Ayurveda, Indian traditional medicine, and classified as medicinal plants[2]. In the fishery and animal husbandry, itis used as additional feed and improve animal performance[3,4].Those continuous utilization in several fields makes turmeric as a profitable plant if to be developed as well.

Bioprospecting is a step need to undertaken in discovering valuable and novel chemical products forpharmacy and other industries purpose.As a medicinal plant,*C. longa*possesses many phytochemicalsthat benefit for human health, e.g. antioxidant, anti-diabetic, anti-inflammatory, anti-cancer, anti-fungal, and anti-viral[5].Those healthy benefits mostly come from curcumin, an active compound, provides color to turmeric[6]. Theyellow pigment in turmeric can also be used in the food product as a natural colorant and shows good market potential[7].Abdeldaiem reported that turmeric pigment can also exhibit antioxidant and antimicrobial activity by reducing lipid oxidation, therefore it is recommended for food preservative[8].Furthermore, the essential oils contained in Curcuma herbs, which has been proven exerted variousbiological activities, might be prospective to be developed as food additives, as well as cosmetics and pharmaceuticals[9].

The presence of all the secondary metabolites understudy having a higher amount of curcumins is found to be impressive. Curcumin showed the highest availability in *C. longa* (125mg/100g), whereas in other species are 8mg/100g, 11mg/100g and 15mg/100g in *C. caesia*, *C. amada* and *C. leucorrhiza*, respectively[10]. Studied on curcumin explained varied results in India. It described that different agro climate zone influenced phytochemicals in plant and *C. longa* var. "Surama" of Eastern had high curcumin content (8.8%) among 60 collected turmeric varietes[11].In addition,many secondary metabolites providing by turmeric.Those proven research revealed that turmeric contains some bioactive compounds that will be useful for human and have a great opportunity in the market.This review study summarizes *C. longa* on its botanical aspect, phytoconstituents, related biological activity of its phytoconstituents, and its potential use for humans, livestock, and fishery.

II. Methods

The method used was literature exploration in the following databases: Directory of Open Access Journals (DOAJ), NCBI, Google Scholar, Research Gate and also using relevant keywords i.e. turmeric, Curcuma longa, biological activity, human and animal health, plant anatomy, morphology, and phytochemical content.

III. Result

Turmeric has a wide range of secondary metabolitesand derivated compounds(Table no 1). It contains saponin, tannin, flavonoid, phenol, and sterol.GC-MC analysis showed fifty compounds in turmeric and dominated by turmerone, β-sesquiphellandrene, and curcumenol[12].The finding of nine secondary metabolites reported possessing antioxidant antivity[13].However, curcumin is a mostly well-known compound that contributes to human and animal health.

Table no 1: Biochemical compound of turmeric

Compound	References
saponin, tannin, flavonoid, phenol and sterol	[14]
fat, fiber, protein, essential amino acids (arginine, histidine, isoleucine, leucine, lysine, methionine, threonine, valine) and non-essential amino acids (alanine, aspartic acid, glutamic acid, glycine, serine, and tyrosine)	[15]
curcuma I, curcuma II, and curcuma III	[16]
phenols, flavonoids, alkaloids, and tannin	[17]
phenols, flavonoids, alkaloids, terpenoids, tannins, and saponins.	[10]
o-cymene; *L-trans*-chrysanthenyl acetate; *DL*-2,3-butanediol; 5-isopropenyl-1,2-dimethylcyclohexan-2-enol; *p*-cymene; (2,4,6-triethylcyclohexyl)methanol; α-thujone; 2-ethenyl-1,1-dimenthyl-3-methylene-cyclohexane; *cis*-sabinol; *cis-p*-menth-2,8-dienol; 2-isopropylidene-3-methylhexa-3,5-dienal; Thymol; 2-methoxy-4-vinyl phenol; *m*-eugenol; Hemellitol; benzene-2-methyl-1,4-bis(1-methylethyl); β-curcumene; α-cedrene; γ-curcumene; β-caryophyllene; ar-curcumene; β-himachalene; α-curcumene; β-elemene; α-cubebene; β-cedrene; β-bisabolene; β-sesquiphellandrene; *cis-z*-α-bisabolene epoxide; β-vatirenene; agarospirol; β-turmerone; curlone; germacrone; α-turmerone; curzerene; dihydrocostunolide; furanodiene; ar-turmerone; isocurcumenol; curdione; curcumenol; 7-epi-*cis*-sesquisabinene hydrate; (–)-isolongifolol; geranyl-*p*-cumene; *cis*-β-elemenone; isoshyobunone; dihydrocostunolide; dehydrosaussurea lactone; corymbolone	[12]
7-O-rhamnoside 4′-O-glucoside, 7-methoxyapigenin-6-C-glucoside and N-(3-methoxyphenyl) acetamide	[18]
bisabolone-9-one;4-methyllene-5-hydroxybisabola-2,10-diene-9-one; turmeronol B; 5-hydroxy-1,7-bis(4-hydroxy-3-methoxyphenyl)-1-hepten-3-one; 3-hydroxy-1,7-bis(4-hydroxyphenyl)-6-hepten-1,5-dione; cyclobisdemethoxycurcumin; bisdemethoxycurcumin; demethoxycurcumin; and curcumin	[13]
8,9-dehydro-9-formyl-cycloisolongifolene, curdione, germacrone, zerumbone, ar-turmerone, and β-elemenone	[9]
3-carene, tumerone, eucalyptol, and alpha-pinene	[19]
guaiacol; vinylguaiacol; (e)-alpha-bergamotene; caryophyllene; beta-bisabolene; alpha-turmerone; curlone; n-hexadecanoic acid; (z)-9,17-octadecadienal; linoleic acid; ethyl-2-hydroxy-1-(hydroxymethyl) hexadecanoate; ethyl-2-hydroxy-1- (hydroxymethyl), (z,z)-9,12; 2-epi-alpha-cedrene; alpha-santalene; alpha-terpineol; eucalyptol; beta-farnesene; ar-curcumene; gamma-curcumene; sesquiphellandrene; gamma-cadinene; (e)-alpha-atlantone; 4-(4-hydroxy-3-methoxyphenyl)-3-buten-2-one; methyl isohexadecanoate; hexadecanoic acid, ethyl ester; 1,2- hexadecanediol; methyl-8,11- octadecadienoate; (z)-gamma-bisabolene; (z,z,z)-9,12,15-octadecatrienoic acid; ethyl-9,12-octadecadienoate; stearic acid; (z)-beta-elemene; (z)-alpha-bisabolene; nerodil; (z,z)-9,12 (z)-alpha-santalol; beta-elemenone; zingiberenol; aromatic-turmerone	[20]
alkaloids, flavonoids, anthocyanins, and phenolics	[21]

The benefit of turmeric and biological activities in terms of health are displayed on Table no 2, while the benefit for livestock and fishery is displayed in Table no 3. Overall, curcumin has a wide range impact on some diseases as an anti-inflammatory, antioxidant, anti-cancer, anti-tumor, anti-bacterial/fungal, and help in curing alzheimer and liver disease. As an additional feed, turmeric can improve the health and performance of livestock such as broiler, rabbit, sheep, and quails. Pigment on turmeric also improvedcaudal fin and muscle color ofguppy[3].

Table no 2: Benefit of phytochemical content in turmeric

Active compound	Biological Activities	Mechanism of Action
Curcumin (dietary turmeric)	Anti-inflammatory	lowering lipid peroxidation[22]
Essential oil	Anti-inflammatory antioxidant, anti-microbial, and anti-cancer	- down-regulating expression of cytokines including COX-2, TNF-α, NF-kB, IKK, Akt and PKC[9] - inhibiting gram-negative, gram-positive bacteria, and fungus[9]
Curcuminoid	Anti-inflammatory and antioxidant	increasing anti-inflammatory or decreasing pro-inflammatory cytokines and activating the antioxidant defense system [23]
Curcumin	Anti-inflammatory (asthma)	resisting IL-6, IL-8, IL-1β and TNF-a as pro-inflammatory markers[24]
Polyphenols	Anti-inflammatory	- modulating NF-kB activation, chromatin structure, glutathione biosynthesis, nuclear redox factor (Nrf2) activation - scavenging effect of ROS directly or via glutathione peroxidase activity and regulating inflammatory genes in macrophages and lung epithelial cells[25]
Aromatic-turmerone	Anti-inflammatory	- inhibiting thetransfer of CD8+ T cells in epidermis[26] - reducing the expression of NF-κB and COX-2[26] - decreasing the level of TNF-α and IL-6[26] - down-regulating mRNA synthesis of IL-17 IL-22 and IL-23[26]
Curcumin	Anti-inflammatory (skin disease)	- uptaking of tritiated thymidine on muscular cells and vascular smooth cells [27] - Inhibiting Aβ-induced expression of Egr-1 protein and Egr-1 DNA-binding activity in THP-1 monocytic cells[28]
Curcumin	Anti-diabetic	- reducing the hepatic glucose production, suppressing of hyperglycemia-induced inflammatory state, up-regulating GLUT4, GLUT2, and GLUT3 genes expressions, activating AMP kinase, promoting the PPAR ligand-binding activity, stimulating insulin secretion, improving in pancreatic cell function, and reducing of insulin resistance[29]
7-O-rhamnoside 4′-O-glucoside,7-methoxyapigenin-6-C-glucoside and N-(3-methoxyphenyl)	Anti-diabetic	- increasing the serum glucose, IgE, nitric oxide, and cytokine levels in diabetic infected rats with *S. aureus*[18]
Curcumin	Anti-inflammatory and antioxidant(cardiometabolic disease)	- inhibiting Aβ and tau accumulation[30] - enhancing mitochondria and synaptic function[30]
Curcumin	Anti-cancer	inducing autophagy[31]
Curcumin	Anti-cancer (lung and breast cancer)	- inhibiting PRMT5 and MEP50 expression[32] - inhibiting TGFβ-receptor-mediated Smad2/3 phosphorylation of MDA-SA, MDA-1833, MDA-2287, and murine 4T1 human cells[33]
Curcumin	Anti-cancer (prostate)	decreasing cell proliferation and increasing apoptosis [34,35]
Curcumin	Anti-tumor	inhibiting LPS-induced activation and reducing the biological activity of TNF[36] suppressing DMBA-induced skin tumors [37]
Curcumin	Anti-bacteria/fungal	- Inhibiting enzyme of topoisomerase I and II[16] - restraining the bacterial activity [38] - inhibiting mycelial growth [39]. - inhibited drug efflux and suppressing*PDR5* expression[40]
Curcumin	Anti-HIV	- interrupting the cell cycle and inducing apoptosis[41] - inhibiting transactivation of HIV1-LTR genome, inflammatory molecules, and HIV associated various kinases [42] - preventing HIV-1 reverse transcription [43] - activating caspases-3 and -8 supporting the rationale that apoptosis occurs via a membrane-mediated mechanism [44]
Curcumin	Anti-inflammatory (alzheimerdisease)	- inhibiting Egr-1 DNA-binding activity[28] - suppressing the inflammatory cytokine IL-1β and the astrocytic inflammatory marker GFAP, reduced oxidative damage, and decreased overall insoluble amyloid, soluble amyloid, and plaque burden [45] - loweringamyloid β (Aβ) accumulation[46]
Curcumin	Antioxidant (liver)	- triggering the up-regulation of antioxidant enzymes and preventing LPO [47]. - restoring hepatic enzymes activities and enhancing catalase activity[48]

Table no 3: Benefit of Turmeric supplementation to livestock and fish

Benefit	Animal	Source
Growth and health promotor	Poultry	[49]
Fat controller; meat and bone quality improver	Broiler	[50]
UV radiation protector	Rabbit	[51]
Subclinical mastitis controller	Sheep	[52]
Cholesterol and triglyceride reducer	Quails	[53]
Growth promotor and anti-microbial	*Nile tilapia*	[54]
Body-color improver	Guppy*Poecilia reticulate*	[3]
Growth promotor	common carp *Cyprinus carpio* L.	[55]
Bacterial inhibitor	Pindangfish, cuttlefish	[5657]

IV. Discussion

Botanical Aspects

*C. longa*is an erect perennial herb.As a part of the Curcuma genus, *C. longa*almost has similar morphology with another Curcuma species. It has leaves in sheaths and fleshy rhizomes[58]. The plant can be identified by several characters includes branched rhizomes, orange to orange-red flesh color, carrot–turmeric smell, and plain green leaves[59].The height can reach approximately 1 m. Leaves are alternate, indirectly erect, or subsessile. It ranges 7-12 number with the length ranges from 30-45 cm and breadth between 14 and 16 cm.The petiole equaling the blade. Oblong or elliptic leaf sheaths of turmeric surround and broaden near the base and formpseudostem. The pseudostem is tall and robust, with oblong/elliptic leaves narrowed at the base.The inflorescence is a cylindrical, fleshy, central spike of 10–15 cm, arising through the pseudostem[58]. *C. longa* habit, flower,and rhizome displayed in Figure no 1.

The leafy shoot may reach a length of up to 5m. The true stem, on the other hand, maybe very short, e.g. *Kaempferia,* where no internodal extension has occurred. The sheaths are long, the lowest ones bear only a rudimentary lamina, whilst at successively higher nodes the shape and size of the lamina increases until the typical form of the foliage leaves is achieved. The lamina is never very small and has a maximum length of about 1 m. In shape, it is most commonly lanceolate and sometimes it is cordate at the base[60].

The rhizomesare composed of different segments and performed in short or long[60]. The color is yellowish-brown to deep brown. Some showed a variety of turmeric color such as orange, lemon yellow, and reddish yellow[61]. Rhizome thickness and weight are respectively 2.60 cm and 74.80 g[62]. The roots emerge from the rhizome only. They may vary in size, slender but are often thick and fleshy, spindle-shaped (globe), or with tuber-like distal thickenings [60].

(a) (b) (c)

Figure no 1:*Curcuma longa* L. a) plant habit b) flowerc) rhizome

Turmeric pollens are spherical and ovoid, nonaperture[63].In *C. zedoaria*the inflorescence stalk without laminate leaves develops directly from a bud on the underground structures (corm and branches). The floral axis rarely exceeds 30 cm in length; with the inflorescence about half the total length. The purple top bracts are the showiest part of the flower spike[64].

Phytoconstituents

Turmeric has primary and secondary metabolites that are different from each other depending on its variety and origin.Turmericisdifferent in carbohydrates, protein, and fat content among branches and root[64]. Carbohydrate is higher in roots while protein is greater in corms, and fat is higher in first-order branches.Analysis of nutritional compositions of turmeric using the standard method explained 8.92 % moisture

content, 2.85 % ash, 9.42 % crude protein, 4.60 % crude fiber, and 6.85 % fat. Kamal et al.explored that total carbohydrate in curcumin powder tended to be high compared with fat, fiber, and protein[15].

Table no 1 showed phytochemical contained in turmeric both from leaves and rhizomes.It containsphenols, flavonoids, alkaloids, terpenoids, tannins, and saponins. Ahamefula et al. reported that the plant contained 0.45 % saponin, 1.08 % tannin, 0.40 % flavonoid, 0.08 % phenol and 0.03 % sterol[14].Besides containing curcumin as interesting phytochemical, Chinedum et al. exhibited that turmeric has anthocyanin which plays a role in antioxidant activity[21]. Some chemicals were also found to have antioxidant activity[13]. On the other hand, there are many phytoconstituent mentioned in Table no 1 that need further assessment about its utilization, especially for human.

Some phytocontituents have gives uniqueness character of turmeric. It contained curcuminoid in huge numbers which are divided into three types curcumin I, curcumin II, and curcumin III[16]. Those compounds are also named curcumin, demethoxycurcumin, bisdemethoxycurcumin[65]. The chemicals affect to yellow color in turmeric. Besides, it containseucalyptolthat influences the characteristic fresh and camphoraceous fragrance and pungent taste of turmeric[66]. Turmerone and ar-turmerone in turmeric contribute to the dry turmeric aroma character[67]. Structured of some compounds in turmeric are displayed in Figure no 2.

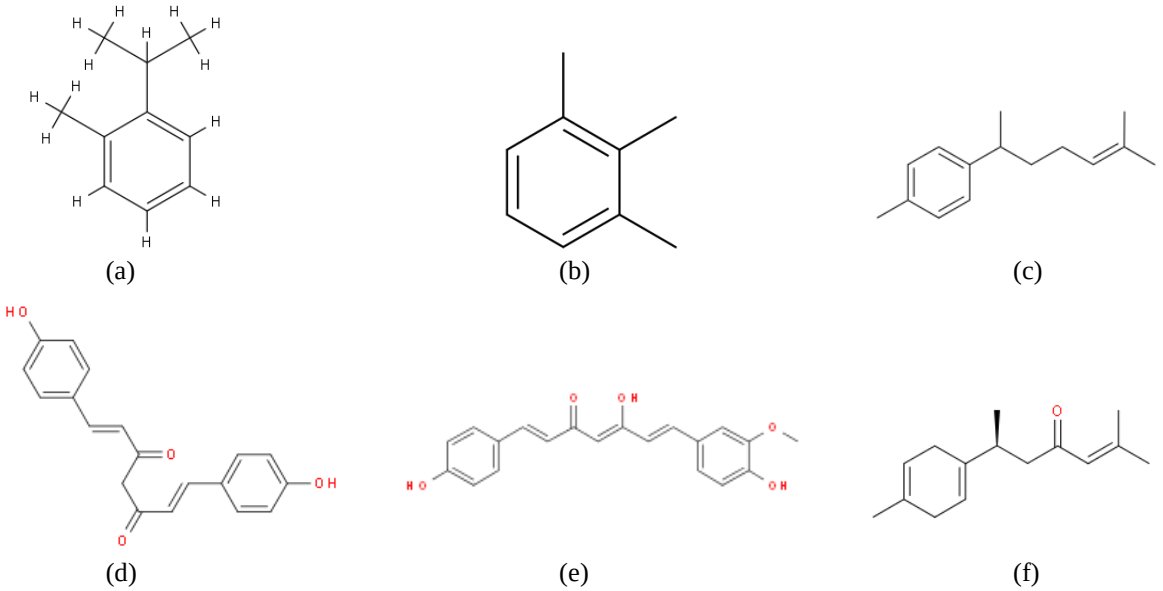

Figure no 2: 2D structure of (a) o-mycene (ChemSpider ID10253); (b) hemellitol (ChemSpider ID10236); (c) ar-curcumene (ChemSpider ID83185); (d) bisdemethoxycurcumin (ChemSpider ID4474770); (e) demethoxycurcumin **(**ChemSpider ID4482000); (f) turmerone (ChemSpider ID30791650)

The percentage of some chemicals are influenced by varieties and growth environment. Indian varieties of turmeric showed variation in essential oil and curcumin content both in leaves and rhizomes[68]. Singh et al. also revealed that bioactive phytoconstituents varied among turmeric genotypes[19]. Thevariation shows that the development of turmeric as a product in the future needs to consider a variety of plants. The level of curcumin in turmericis correlated with the length of planting time[69].In addition, ascorbic acid and phenolic contents in leafwerecorrelated positively with the maturity of leaf[70].

Biological Activities

Some compounds in turmeric have its biological activity in dealing with disease, especially curcumin[71].It can be anti-inflammatory simultaneously with antioxidant and anti-cancer. Those bioactivitiescan improve human health includes AIDS, alzheimer disease, cancer, diabetes, and liver. It cannot be denied curcumin is the most prominent compound to influence mechanisms in the human body. As an anti-inflammatory, curcuminaffected in accelerated healing of the irradiated wound or skin inflammation[72].Another anti-inflammation mechanism is surppressing the expression of cytokine, reducing pro-inflammatory cytokines, modulating NF-KB, reducing gene expression related inflammation (Table no 3).

As antioxidant, curcumin encourages scavenging free radicals from biological media by involving H-abstraction and addition reaction up to eight OH radicals[73,74].Compared to ginger in ayurveda/chinese, turmericsignificantly activatesthe antioxidant defense system[23]. Those bioactivities both anti-inflammatory and

antioxidant help curing people with alzheimer desease by suppressing indices of inflammation and oxidative damage[45] and lower amyloid β (Aβ) accumulation[46].

Curcumin has been found to possess anti-cancer activities involved such as mutagenesis, oncogene expression, cell cycle regulation, apoptosis, tumorigenesis, and metastasis[75].It can also medicate tumors in human by influencing avariety of growth factor receptors and cell adhesion molecules involved in tumor growth, angiogenesis, and metastasis[76]**.**Additional turmeric in the diet significantly prevented the BP-induced forestomach tumors and suppressed DMBA-induced skin tumors[37].Besides, it can treat diabetes by reducing the level of blood glucose[29].As curcumin has wide range utilization, it cannot be separated fromthe turmerone compound. Yue et al. reported that turmerone helped curcumin absorption and improved RH-123 efflux and mRNA expression[77]. All the benefits mentioned above are a wide-open opportunity to develop turmeric as a medicinal plant for drug purposes.

Utilization forLivestockand Fishery

Turmeric has many advantages for livestockand fishery. Turmericprovides an alternative method of natural antibiotic to feed poultry farm and influence growth performance and weight gaining[49], yolk color, egg quality, blood, and liver biochemical parameters of the eggs[53].Additional Turmeric Rhizome powder (TRP) in broiler affect broiler performance especially fat, heart, and bone[50].Therefore, it is recommended to add turmeric rhizome powder as a supplementary feed.

According to animal health, turmeric prevent animal reproductive system damage caused by UV radiation[51], subclinical mastitis[52]. Subclinical mastitis attack mammary gland and mainly caused by*Staphylococcus aureus* and *Mannheimia haemolytica*[78]. Since the sheep is a milk producer, the health status affected milk quality and quantity[79]. Hence, turmeric addition in feed benefit animal in dealing with the disease. Additional turmeric in feed was also reported to reduce total bacteria count as well as anti-inflammatory and anti-bacterial activites[52]. However, there must be deep research about side effect on mixing turmeric as animal feed.

Some studies have found the effect of turmeric on fish. In fishery, additional turmeric as a supplement influencedfish body composition like crude protein content and protect *Nile tilapia* fish against *P. fluorescens*[54]. It was also described that *Curcuma* powder had beneficial effects on final weight, weight gain, and specific growth rate of *Cyprinus carpio* L[55].Turmeric application for fish diet was reported to have no hepatotoxic effect, but at a higher dose affect gill toxic[4].

However, in ornamental fish, turmeric-mixed feed gave additional color effect due to pigment concentration on the fantail of guppy *Poeciliareticulate*[3]. The importance of carotenoid pigment had been studied and reported indispensible with ornamental fish market acceptability[80]. Thus, involving some pigmented natural sources in fish feed need to be further studied.

Turmeric is a valuable fishery product and has potential use in the fish-processing industries. It can decrease the total number of pathogenic bacteria such as *Escherichia coli*, *Staphylococcusaurens*, *Salmonella*, and *Vibrio cholera*[56]. Moreover, applied turmeric extract to *Sepia brevimana*(cuttlefish) muscle showed an inhibitory effect against some potential BA-forming bacteria[57]. That revealed the ability of turmeric extract to improve the shelf life and quality of *S.brevimana* muscle at 4°C without changing its appearance, flavor, and texture up to day 15 of storage. It can be concluded that turmeric have preservative effect against spoilage bacteria.

V. Conclusionand Future Perspectives

This review revealed that *C. longa*is very potential for human health, livestock, and fishery.Turmeric is prosperous in the drug industry as well as livestock product and spasious market of ornamental fish. The most prominent constituent in *C. longa*,namely curcumin, plays rolesas antioxidant, anti-inflammatory, anti-bacterial, anti-cancer, anti-HIV, anti-diabetic. Those biological activities determine curcumin as a natural agent to treat liver, tumor, cancer,and alzheimer disease in human. Moreover, *C. longa* benefitsfor livestock can be used as agrowth promoter, health protector, and quality and quantity product improver. Additional turmeric to feed can be used as a bacterial inhibitor and source of pigment, especially for ornamental fish. In the future, the development of turmeric superior variety through breeding can lead to the right market, therefore adding more value to our natural resources.

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