Vol. 14(9), pp. 519-531, 28 February, 2019
DOI: 10.5897/AJAR2018.13755
Article Number: 21C6ECE60377
ISSN: 1991-637X

http://www.academicjournals.org/AJAR

ACADEMIC JOURNALS
expand your knowledge

African Journal of Agricultural Research

Review

A review on golden species of Zingiberaceae family around the world: Genus *Curcuma*

Ewon Kaliyadasa* and Bhagya A. Samarasinghe

Department of Export Agriculture, Faculty of Animal Science and Export Agriculture, Uva Wellassa University, Badulla, Sri Lanka.

Received 23 November, 2018; Accepted 11 February, 2019

Genus *Curcuma* has a long history of traditional uses, ranging from folk medicine to its culinary uses. More than 70 species of *Curcuma* are distributed throughout the world but extensively cultivate in Asian, Australian and Western African counties. Many phytochemical, pharmacological and molecular studies have been conducted on several *Curcuma* species worldwide. The interest on its medicinal properties have increased due to the discovery of novel bioactive compounds which possessing wide range of bioactivities such as antioxidant, antiviral, antimicrobial, and anti-inflammation activities. Furthermore, this valuable plant is used as natural dye, insecticide and as a repellent. This review focuses on gathering information regarding genus *Curcuma* including morphological characteristics, phytochemicals and their biological and pharmacological activities which provide information for further advance research studies.

Key words: *Curcuma*, biological activity, morphology, pharmacology, phytochemicals.

INTRODUCTION

The genus *Curcuma* belongs to the family Zingiberaceae comprises rhizomatous annual or perennial herbs. According to Xia et al. (2005), the genus *Curcuma* comprises of 70 species, which are distributed widely throughout tropical and subtropical regions of the world. Out of 70 species, about 40 species are reported from India (Pemba and Sharangi, 2017). However, the exact number of species is still controversial (Akarchariya et al., 2017). *Curcuma* naturally found in India to Thailand, Indochina, Malaysia, Indonesia, and finally spreads to northern Australia. *Curcuma* is extensively cultivated in tropical and subtropical regions of Asia, Australia, Western Africa and South America (Ravindran et al., 2007). The species are naturally found in tropical forests and tropical broad-leaved evergreen forests.

Curcuma is an economically important genus having many different uses. It is used as spices, food preservatives, flavouring agent, medicines, dyes, cosmetics, starch and ornamentals (Xiang et al., 2011; Sahdeo and Bharat, 2011). The underground rhizome of *Curcuma* is an important source of a yellow dye (Srivilai, et al., 2018). The word "*Curcuma*" is derived from the Arabic word "Kurkum" which means yellow colour (Su et al., 2017). They have been used for the treatment of various diseases like enlarged liver, spleen, stomach ulcer, diabetes, cough, hepatic disorders, chest pain, skin diseases, boils, blood purifier, and rheumatism (Saikia and Borthakur 2010). Various parts of these plant species

*Corresponding author. E-mail: ewon101k@yahoo.com. Tel: +94718310540.

have been used either raw or cooked as vegetables in many Asian countries (Devi et al., 2014). They also considered as nutritionally rich foods because *Curcuma* plants are a rich source of starch, carbohydrates, proteins, fats, vitamins, and minerals (Roshan and Gaur, 2017).

Curcuma plants have been shown to contain various bioactive molecules, which possesses many pharmacological properties such as; anti-inflammatory (Sikha et al., 2015), antimicrobial (Jagtap, 2015), hypocholestraemic (Shafreen et al., 2018), antirheumatic (Abdel-Lateef et al., 2016), antiviral (Pant et al., 2013), antifibrotic (Jose et al., 2014); antihepatotoxic (Jagtap, 2015); antidiabetic (Nwozo et al., 2014); antinociceptive (Ramasree and Indira, 2006); anticancerous (Pawar et al., 2011); gastroprotective properties (Jeon et al., 2015) and beneficial effects on cardiovascular diseases (Nithya and Jayashree, 2017). Plants belonging to the genus *Curcuma* are gaining importance all over the world and subjected for many investigation and exploration in recent years due to its promising potentials and wide range of usage. Therefore, a proper morphological and physicochemical identification is necessary, but not systematically studied yet. This review intends to provide a comprehensive insight into the morphology, phytochemistry and pharmacology of the genus *Curcuma.*

STUDIES ON GENUS *CURCUMA*

Several reports have been published concerning the phytoconstituents, essential oils, and pharmacological actions of *Curcuma* (Faiz et al., 2015; Abdel-Lateef et al., 2016). The significance of the genus *Curcuma* has been recognized since the discovery of the antioxidant properties. The dried rhizome of *Curcuma longa* L has been found to be a rich source of beneficial phenolic compounds known as the curcuminoids (Lechtenberg et al., 2004). The most important of *Curcuma* species, *C. longa*, is commercially known as turmeric plant. Since Vedic age turmeric has been used as spice, herbal medicines, dyeing agents and cosmetics (Shirgurkar et al., 2001). Phytochemical investigations have been reported three main curcuminoids called curcumin, demethoxycurcumin and bisdemethoxycurcumin, which are characteristically developing yellow pigmentation to turmeric rhizome (Lechtenberg et al., 2004).

Curcumin is the main active constituent, which is a curcuminoid present in genus *Curcuma*. Even though environmental factors influence its stability, curcumin is an important secondary metabolite whose biosynthesis involves genetic control (Anandaraj et al., 2014). The chemical composition of *Curcuma longa* has been studied extensively. A number of biologically active components have been identified with antioxidant, anti-tumour, germicidal, aromatic, carminative, anti-helmentic, cholesterol lowering and neuroprotective properties and turmeric has been also used for the treatment of dyspepsia, peptic ulcers and gastric ulcers through pharmacological and clinical studies (Sikha et al., 2015, Shafreen et al., 2018; Jose et al., 2014; Jagtap, 2015). In addition, wound healing and detoxifying properties of curcumin have also reported (Jagtap, 2015).

Some *Curcuma* species such as *Curcuma aeruginosa, Curcuma amada, Curcuma angustifolia, Curcuma caesia, Curcuma elata, Curcuma petiolata, Curcuma rubescens, Curcuma zanthorrhiza* and *Curcuma zedoaria* produce beautiful inflorescences and foliages that have a commercial value in floriculture as ornamental crops (Maciel and Criley, 2003). Among them *Curcuma alismatifolia* is recognized and popular in international trade as cut flower (Paisooksantivatana and Thepsen, 2001). Even though Curcuminoids have been approved by the US Food and Drug Administration (FDA) as “Generally Recognized As Safe” (GRAS) with good tolerability and safety profiles, which is proven by clinical trials (Gupta et al., 2013). There is limited literature available for studies related to curcuminoids as food value, nutritional composition, and health benefits of the edible *Curcuma* species (Sanatombi and Sanatombi, 2017).

Many morphological and physiochemical studies have been reported on commonly used plant parts of the *Curcuma* such as rhizome (Satyendra et al., 2013), leaves (Cuellar et al., 1998), stem (Dung et al., 1997), roots (Dung et al., 1996), inflorescence/ flowers and buds (Dung et al.,1998) and Entire plant (Maikhuri and Gangwar, 1993). From all evidences, the leaf, flowers, fresh and dry rhizomes are important in obtaining different phytochemical effects as a medicine as well as for other uses.

MORPHOLOGICAL CHARACTERISTICS OF GENUS *CURCUMA*

Many researchers have been studied the morphological characteristics of different species in genus *Curcuma*. When one consider the Morphology, the genus *Curcuma* is highly variable in taxonomically important traits. Four tribes in family Zingiberaceae were recognized namely, *Globbeae, Hedychieae, Alpinieae* and *Zingibereae* based on morphological features like number of locules and placentation in the ovary, development of staminodes, modifications of the fertile anther, and rhizome-shoot-leaf orientation (Kress et al., 2002) where *Curcuma* is belongs to Zingibereae.

Commonly the rhizomes of *Curcuma* are branched, fleshy and aromatic (Revathi and Malathy, 2013). Roots attached to the rhizome often bear conical or ellipsoid tubers (Dung et al., 1997). Basal leaf blades are normally broad, lanceolate or oblong or rarely linear in shape (Cuellar et al., 1998). Flowers contain a single versatile anther and spiral bract with large compound spike inflorescence is a prominent characteristic when

recognizing the genus *Curcuma* (Dung et al., 1998). The terminal bracts form a sterile cluster is very long and often brightly coloured (Dung et al., 1998). It has two distinct flowering times. Early flowering species develop flowers laterally from rhizomes before the development of leafy shoots and late flowering species usually developed terminally from the leafy shoots (Sirirugsa, 1998). The plants are normally 50 to 200 cm in height. *Curcuma* species are mostly triploid and reproduce asexually by rhizomes. They do not produce seeds (Malek et al., 2006). Morphology of the different early flowering *Curcumas* lead to identification problems because they exhibit large intra- and inter specific morphological variations.

C. longa rhizome is medium sized, aromatic and conical in shape. The internal colour of the rhizome is deep orange-yellow (Abdel-Lateef et al., 2016). They are native to Southeast Asia, southern China, the Indian Subcontinent, New Guinea and Northern Australia and naturally found in some warm regions of the world such as tropical Africa, Central America, Florida, and various islands of the Pacific, Indian and Atlantic Oceans. It has cylindrical and branched sessile tubers. Leaf lamina is oblong-lanceolate with wavy margins and short ligules. Inflorescence is in the middle. The peduncle concealed within the leaf sheaths Spike has a distinct white coma and bracts are pale green. Corolla tube of the large flowers are white in colour with unequal lobes. Labellum is light yellow in color with a median dark yellow band. Lateral staminodes are linear and anthers are spured (Kress et al., 2002).

C. amada Roxb. consists of a large rhizome which is light yellow in colour inside and white towards the periphery, with the smell of green mango being found in southern India (Policegoudra et al., 2010). It has branched sessile tubers, which are thick and cylindrical or ellipsoid in shape. Roots are fleshy and tubers are absent. Pseudostem is 30 to 35 cm tall. The leaf laminas are oblong or lanceolate with puberulous lower surface and glabrous upper surface. Inflorescence is lateral or central with a peduncle covered by sheaths. Spike is light violet with fused coma bracts at base. Bracts are obtuse and green in colour. Corolla tube of the large flowers are funnel shaped and pale yellow in colour with unequal white lobes (Rao et al., 1989). Labellum is elliptical and pale yellow with a median dark yellow band. Stamens are white thecae and the basal spur is convergent. Ovary has many ovules with dense hairs. Style is long and filiform. Stigma is closely appressed within the anther lobes (Faiz et al., 2015).

C. zedoaria has a large rhizome that is deep yellow in colour. The plant is native to India and Indonesia but now naturalized in other places including the US state of Florida. The sessile tubers are thick and branched (Newman et al., 2004). The roots are thick and fleshy with fusiform fleshy pearl white root tubers. Oblong-lanceolate leaf lamina is having purple coloured patches on the upper side along the whole midrib, which fades in older leaves. Inflorescences are laterally placed with peduncle. Spike has a distinct coma that is fused at the base and dark pink in colour. Fertile bracts are ovate, green with pink margin. 4-5 flowers are in each bract. Funnel shaped corolla tube is white in colour. Labellum is pale yellow in colour with a deep yellow band (Chen et al., 2013).

Curcuma aromatica has an aromatic yellow rhizome with many sessile tubers. The plant is native to Kerala, Karnataka, Orissa and Bihar in India. Leaf lamina is broadly lanceolate, acuminate and lower surface has dense pubescents (Choudhury et al., 1996). Coma bracts in inflorescences are large, spreading and pink in colour (Singh et al., 2002). Fertile bracts pale greenish-white in colour with hairs on upper surface. Corolla tube is funnel-shaped, pinkish-white in colour with unequal lobes. The dorsal lobe is broadly ovate arching over the anther and hooded. The lateral lobes are oblong and narrow. Labellum is deep yellow in colour. Lateral staminodes are oblong, obtuse and long, filiform (Jeon et al., 2015).

Curcuma caesia Roxb has a large rhizome, which is strongly aromatic. It is native to North-East and Central India. Rhizome is blue in colour in the centre, varying towards grey depending on the nature of the soil and age. The roots are fleshy with many root tubers, which are sessile, and branched (Sarangthem and Haokip, 2010). Distichous leaves with petiole are oblong to lanceolate with acute tip and acuminate base. Glabrous purple or reddish-brown patch is present along the sides on the distal half of the mid rib on upper surface (Paliwal et al., 2011). Large coma bracts present within the inflorescence are pink to violet in colour. Flowers are slightly shorter than the bracts. Corolla tube is long, pink in colour with unequal lobes. Ovary is trilocular with many ovules (Vairappan et al., 2013).

Curcuma haritha has non-aromatic large yellowish grey colour rhizome. It is native to Kerala in India. There are many finger shaped, long and branched sessile tubers. Roots are numerous and fleshy. Ovate- elliptical shaped leaf sheaths with acuminate tip and acute base are green in colour with light pink dots. The leaf is thick, leathery, densely puberulent on the lower surface and sparsely hairy above. Inflorescence is lateral and coma is fused only at the base and bright pink in colour. The lower bracts are fully green in colour whereas the upper ones are green with pink tips. Flowers are slightly smaller than the bracts. Corolla tube white in colour (Kress et al., 2002).

Curcuma ecalcarata has small yellow colour rhizome without sessile tubers (Revathi and Malathy, 2013). It is native to Kerala in India. Leaf lamina is broadly ovate, acuminate and densely pubescent on the lower surface. Inflorescences are centrally located with a pubescent peduncle. Coma bracts are longer and bright pink or greenish-white. Flowers are yellow or orange-yellow in colour and longer than the bracts (Sirirugsa, 1998).

Curcuma oligantha has a small rhizome. It is non-aromatic and internal colour is yellow. Sessile tubers are absent. Leaves are distichous and the lamina is ovate-elliptic in shape with acuminate tip and oblique base. Inflorescence is lateral and there is no any distinct coma. Fertile bracts are green in colour with a pinkish tinge. Flowers are longer than the bracts. There are many seeds produced in this species (Lai et al*.,* 2004).

Curcuma raktakanta rhizome is medium sized, whitish towards the periphery and aromatic. The plant is naturally distributed in Kerala, India. There are many fleshy roots. Leaves are distichous and petiolate. The green leaf lamina is oblong-lanceolate with acuminate base and tip. Reddish-purple sheaths and the spike long with a distinct coma cover inflorescence. Flowers are as long as the bracts. Style is long and filiform. Stigma is slightly exerted from the anther. Fruiting is unknown (Kim et al*.,* 2007). Rhizome of *Curcuma aeruginosa* is large (Pandey and Chowdhury, 2003). It is yellowish green colour in the centre and strongly aromatic (Angel et al*.,* 2014). The sessile tubers are branched and condensed. Leaves are distichous and oblong-lanceolate in shape. Leaf tip is acute and base is acuminate. A purple or reddish-brown patch is present along the sides of the distal half of the mid rib on upper side. Coma bracts are pink to violet in colour. Flowers are slightly shorter than the bracts. Ovary is trilocular with many ovules (Kamazeri et al*.,* 2012).

Curcuma angustifolia has narrow, green, glabrous leaves. It is most commonly found growing wild in India, especially in the northeast and western coastal plains and hills. Such areas include the states of Maharashtra, Madhya Pradesh, Andhra Pradesh, Himachal Pradesh, Orissa (Odisha), Chhattisgarh, Tamil Nadu, and Kerala. This species can also be found in Burma, Laos, Nepal, and Pakistan. Small inflorescences are bearing yellow flowers with pink coma bracts (Sharma, 2012). Flowers usually appear near to the ground in the beginning of the rainy (Jena et al., 2017). Species is endemic to northwestern, central, and south India. *Curcuma australasica,* commonly known as Cape York lily, is an endemic species and the only native representative of the genus from Australia (Sharma, 2012). The plant species is usually distributed along the coast of the Gulf of Carpentaria and New Guinea and shady rainforest margins of the Cape York Peninsula in northern Queensland (Sharma et al*.,* 2011). *Curcuma caulina* is an herbaceous perennial plant producing unbranched, erect, leafy pseudostems. Underground rhizome is bearing inflorescence with prominent greenish white or pinkish white colored bracts and yellow or white colored flowers (Sharma, 2012). The plant is reported to be a native of India that grows in the wild in areas of high annual rainfall (Pukhrambam, 2002).

Rhizome of *Curcuma leucorrhiza* is a source of an edible starch (Huxley, 1992). According to the Grieve (1971), it is a stemless perennial plant growing up to 60 cm tall. *Curcuma manga* is commonly known as "mango turmeric" because it has a mango-like smell of rhizome as in *Curcuma amada* (Sharma, 2012). It is an herbaceous, perennial plant producing clumps. Erect pseudostems are emerging from a branched underground rhizome. It grows commonly in Java and Thailand (Liu and Wu, 1999). *Curcuma phaeocaulis* is widely distributed in southern regions of China (Sharma, 2012). This plant has similar characteristics as *C. zedoaria*, *Curcuma caesia,* and *Curcuma aeruginosa* (Sharma, 2012). Inflorescences are arising from pale blue, green, yellowish green or yellow colour rhizomes on separate shoots (Sirirugsa et al*.,* 2007).

Curcuma pierreana is a herbaceous perennial plant. It has originated in Cambodia and Thailand (Tyag, 2005). Rhizomatous rootstocks are producing clumps of leafy stems. Inflorescences are sessile and have white staminodes with large purple-blotched apices (Huxley, 1992). *Curcuma pseudomontana* is grown as a potential ornamental species in Karnataka, Maharashtra, and Andhra Pradesh and endemic to the Western and Eastern Ghats of peninsular India. It has beautiful well-developed coma, with deep yellow flowers and broadly ovate and prominently sulcate leaves with bright green color (Sharma, 2012). *Curcuma purpurascens* is a perennial herb with pseudostems arising from a branched rhizome and wide leaf blades. It is considered as a less known *Curcuma* species, due to limited phytochemical and biological investigations on this plant (Rajashekhara and Sharma, 2010). *Curcuma zanthorrhiza* is a deeply colored rhizome native to Indonesia and was used as a dye. Nowadays it is often used as a substitute for *Curcuma aromatica* in cosmetics. The plant bears a cluster of erect pseudostems an underground rhizome and each pseudostem is made up of about eight long leaves (Ravindran et al., 2007).

PHYTOCHEMICALS OF GENUS *CURCUMA*

The rhizomes of the *Curcuma* species are the most commonly used part for chemical extractions. Non-volatile curcuminoids and volatile oils are the main active components of the rhizome. Curcumin, demethoxycurcumin and bisdemethoxycurcumin are the major curcuminoids. They are nontoxic polyphenolic derivatives of curcumin. Sesquiterpenoids and monoterpenoids are identified as the major components in *Curcuma* oil (Xiang et al*.,* 2018).

C. longa is the major species subjected to many studies. It contains protein (6.3%), fat (5.1%), minerals (3.5%) and carbohydrates (69.4%) (Anjusha and Gangaprasad, 2014). The essential oil (5.8%) obtained by steam distillation of rhizomes contains *a*-phellandrene, sabinene, cineol, borneol, zingiberene and sesquiterpines (Zhang et al*.,* 2017). Curcumin (diferuloylmethane) is the compound responsible for the yellow colour, and comprises curcumin I (94%), curcumin II (6%) and

curcumin III (0.3%) (Xiang et al., 2018). Chemotypes in the turmeric vary widely. There are hundreds of compounds identified from the turmeric essential oils such as; *ar*-turmerone, α-turmerone, and β-turmerone, followed by notable amounts of α-zingiberene, curlone, *ar*-curcumene, α-santalene, santalenone, β-sesquiphellandrene, (Z)-β-ocimene, β-bisabolene, β-caryophyllene, α-phellandrene, (Z)-β-farnesene etc (Angel et al., 2014). There is a significant variation in between the essential oils obtained from fresh and dry rhizomes of *Curcuma longa* (Kutti and Lingamallu, 2012). Oil extracted from rhizome of *C. zedoaria* is mainly composed of sesquiterpenoids and monoterpenoids (Purkayastha et al., 2006). Essential oils in *Curcuma aeruginosa* is usually composed of relatively equal amounts of monoterpenes and sesquiterpenes such as; 8,9-dehydro-9-formyl-cycloisolongifolene (35.3%), dihydrocostunolide (22.5%) (Kamazeri et al., 2012), germacrone (23.5%), curzerenone (11.8%) (Theanphong et al., 2015), dehydrocurdione (27.6%), curcumenol (15.1%), 1,8-cineole (22.7%), germacrone (17.7%) (Srivilai et al., 2018). Generally, monoterpenes are predominated (80–88%) in rhizomes of *Curcuma zanthorrhiza* (Akarchariya et al., 2017). The major constituents in *Curcuma aromatica* rhizome consisted with 8,9-dehydro-9- formyl-cycloisolongifolene (2.7-36.8%), germacrone (4.3-16.5%), *ar*-turmerone (2.5-17.7%), turmerone (2.6–18.4%), curdione (50.6%), camphor (18.8-32.3%), xanthorrhizol (26.3%), *ar*-curcumene (19.5%), di-*epi*-*α*-cedrene (16.5%), curcumol (35.8%), and 1,8-cineole (12.2%) (Tsai et al., 2011). *Curcuma phaeocaulis* rhizome has 8,9-dehydro-9-formyl-cycloisolongifolene (15.6-46.2%), germacrone (8.9-21.2%), and curlone (0.8-20.2%) as the main constituents (Zhang et al., 2017). *Curcuma caesia* composed mainly of 1,8-cineole (30.1%) followed by camphor, *ar*-curcumene, and camphene (Angel et al., 2014).

However, different *Curcuma* species produce a wide variety of volatile sesquiterpenes, monoterpenes, and other aromatic compounds (Singh et al., 2010). There is a significant variation in composition of *Curcuma* essential oils. Genotype, variety, geographical location, climate, season, cultivation practices, fertilizer application, stress during growth or maturity, harvesting time, stage of maturity, storage, extraction, and analysis methods will greatly determine different oil chemical profiles (Sanghamitra et al., 2015; Srinivasan et al., 2016). However, some of the variation could be due to misidentification of the plant species or some of the components (Noura and William, 2018).

PHARMACOLOGICAL ACTION OF GENUS *CURCUMA*

Phytochemicals of *Curcuma* species possesses a wide variety of pharmacological properties, including anti-inflammatory (Sikha et al., 2015), anticancerous (Li et al., 2014), antiproliferative (Oon et al., 2015), hypocholesterolemic (Shafreen et al., 2018), antidiabetic (Nwozo et al., 2014), antihepatotoxic (Fagodia et al., 2017), antidiarrheal (Fouad et al., 2017), antimicrobial (Jagtap, 2015) and insecticidal (Fouad et al., 2017) activities. *Curcuma* oils are also known to enhance immune function, promote blood circulation, accelerate toxin elimination, and stimulate digestion (Raut and Karuppayil, 2014). *C. longa* and *C. zedoaria* are the most widely studied species of genus *Curcuma* (Noura and William, 2018).

Antioxidant activity

Curcumin has the ability to improve systemic markers of oxidative stress (Sahebkar et al., 2015). It can increase serum activities of antioxidants such as superoxide dismutase (Panahi et al., 2016a). Curcumins can scavenge different forms of free radicals, such as reactive oxygen (ROS) and nitrogen species (RNS) (Menon and Sudheer, 2007). Also, it can inhibit ROS-generating enzymes such as lipoxygenase/ cyclooxygenase and xanthine hydrogenase/oxidase (Lin et al., 2007). In addition, curcumin is an efficient scavenger of peroxyl radicals like vitamin E. Therefore, curcumin is also considered as a chain-breaking antioxidant (Priyadarsini et al., 2003). The antioxidant mechanism of curcumin is attributed to its unique conjugated structure, which includes two methoxylated phenols and an enol form of β-diketone (Fagodia et al., 2017).

Anti-Inflammatory activity

Curcumin blocks nuclear factor activation increased by several different inflammatory stimuli. Curcumin is effective against carragheenin-induced oedema in rats and mice. In addition, curcumin stimulates stress-induced expression of stress proteins and may act in a way similar to indomethacin and salicylate. Moreover, curcumins enhance wound-healing in diabetic rats and mice and in H_2O_2-induced damage in human keratinocytes and fibroblasts (Panahi et al., 2016b).

Anticarcinogenic effect

Induction of apoptosis of curcumins plays an important role in its anticarcinogenic effect. It inhibits cell-cycle progression and cancerous cell growth in rat aortic smooth muscle cells (Chen et al., 2013). Curcumin induces apoptotic cell death by DNA-damage in human cancer cell lines via acting as topoisomerase II poison (Martin-Cordero et al., 2003). Curcumin rapidly reduces the potential in mitochondrial membrane to release of

cytochrome *c* (Jana et al., 2004). Curcumin can induce apoptosis by enhancing tumour necrosis factor-related apoptosis-inducing ligand (Deeb et al*.,* 2003). Curcumin delays apoptosis along with the arrest of cell cycle at G1 phase in colorectal carcinoma cell line (Chen et al*.,* 2013). Furthermore, curcumin produces nonselective inhibition of proliferation in several leukaemia, nontransformed haematopoietic progenitor cells. Curcumin suppresses human breast carcinoma and cancer cells through multiple pathways (Li et al*.,* 2014).

Antimutagenic activity

Curcumin has been shown to reduce the number of aberrant cells in cyclophosphamide- induced chromosomal aberration in Wistar rats at 100 and 200 mg/kg body weight doses (Shukla et al*.,* 2002). *Curcuma longa* has the ability to prevent mutation in urethane models (Hamss et al., 1999).

Anti-tumour activity

Germacrone from *Curcuma aromatica* inhibits the proliferation of glioma cells by promoting apoptosis and inducing cell cycle arrest. It also concluded that germacrone might be a novel potent chemo preventive drug for gliomas via regulating the expression of proteins associated with apoptosis and G1 cell cycle arrest (Liu et al., 2014). Beta-elemene isolated from the rhizome of *C. aromatica* is associated with the growth of hepatoma in mice on cellular proliferative activity (Wu et al*.,* 2000).

Anticoagulant activity and Anti-platelet activity

Curcumin inhibits collagen and adrenaline-induced platelet aggregation in *in vitro* as well as *in vivo* in rat thoracic aorta (Su et al*.,* 2017). According to Jantan et al*.,* 2008, Curcumin isolated from *Curcuma aromatica* was the most effective antiplatelet compound as it inhibited arachidonic acid (AA), collagen and ADP-induced platelet aggregation with $IC_{(50)}$ values of 37.5, 60.9 and 45.7 microM, respectively.

Antifertility activity

The 100% antifertility effect has been reported in rats with petroleum ether and aqueous extracts of turmeric rhizomes when fed orally (Garg, 1974). Curcumin inhibits 5α-reductase, which converts testosterone to 5α-dihydrotestosterone, thereby inhibits the growth of flank organs in hamsters (Liao et al*.,* 2001). Curcumin also inhibits human sperm motility (Rithaporn et al*.,* 2003).

Antitussive activity

Antitussive effect on Sulfur dioxide induced cough model in mice suggested that the *Curcuma aomatica* extract exhibited significant antitussive activity in a dose dependent manner (Marina et al*.,* 2008).

Antimelanogenic activity

Antimelanogenic effects of *C. aromatica* extracts were investigated with Ultraviolet A (UVA) irradiation, leading to melanogenesis, which is associated with melanoma skin cancer and hyperpigmentation by assessing tyrosinase activity, tyrosinase mRNA levels, and melanin content in human melanoma cells. This study demonstrated that UVA mediated melanin productions were suppressed by *C. aromatica* extracts at non-cytotoxic concentrations (Panich et al., 2010).

Anti-nephrotoxic activity

C. aromatica leaf extract were studied on nephrotoxicity induced by arsenic trioxide in rats and the results revealed that leaf extract has a potential to modulate the renal dysfunction caused by arsenic trioxide (Saxena et al*.,* 2009).

Antidiabetic activity

Galactose-induced cataract formation can be prevented by very low doses of curcumin (Suryanarayana et al*.,* 2003). Blood sugar level in alloxan-induced diabetes in rat is decreased by curcumin (Arun and Nalini*,* 2002). Advanced glycation products induced complications in diabetes mellitus also can be reduced by curcumin (Nwozo et al*.,* 2014). Ethanolic extract containing both curcuminoids and sesquiterpenoids is more powerfully hypoglycemic than either curcuminoids or sesquiterpenoids (Nishiyama et al*.,* 2005).

Antifungal activity

Prevention of fungal growth may depend on concentration of curcumin. Dried powder of *Curcuma* rhizome addition in plant tissue culture at the 0.8 and 1.0g/L had considerable inhibitory activity against fungal infections (Ungphaiboon et al*.,* 2005). The methanolic extract of *C. longa* showed antifungal activity against *Cryptococcus neoformans* and *Candida albicans* with values of 128 and 256 µg/mL respectively (Kim et al*.,* 2003). Hexane extract of *C. longa* has antifungal effect against *Rhizoctonia solani, Phytophthora infestans*, and *Erysiphe graminis* (Chowdhury et al*.,* 2008). Curcumin oil

showed antifungal effect against *Fusarium solani* and *Helmintho sporium* (Prucksunand et al., 2001). It was reported that 18 months old and freshly distilled oil isolated from rhizome of *Curcuma longa* exhibited the most potent antifungal effect against 29 clinical isolates of dermatophytes with values of 7.2 and 7.8 mg/mL, respectively. Curcumin showed more potent significant effect against *Paracoccidioides brasiliensis* than fluconazole and it did not affect the growth of *Aspergillus* species (Martins et al., 2009).

Antibacterial activity

Curcumin and the oil fractions extracted from *Curcuma* species can suppress the growth of several bacteria like *Streptococcus*, *Staphylococcus*, *Lactobacillus*, etc (Bhavani and Sreenivasa, 1979). The aqueous extract of *Curcuma longa* rhizomes has shown antibacterial effects (Kumar et al., 2001). Curcumin also prevents growth of *Helicobacter pylori* CagA+ strains *in vitro* (Mahady et al., 2002).

Antiviral activity

Curcumin acts as an inhibitor of Epstein–Barr virus key activator BamH fragment Z left frame 1 (BZLF1) protein transcription in Raji DR-LUC cells (Taher et al., 2003). Curcumin in the course of inhibitory activity against the enzyme called inosine monophosphate dehydrogenase (IMPDH) is flexible as a potent antiviral compound (Dairaku et al., 2010). According to the Li et al., 1993, curcumin to be an effective compound to inhibit the HIV-1 LTR-directed gene expression without any major effects on cell viability. Moreover, curcumin reserved the acetylation of Tat protein of HIV significantly by p300 related with invasion of HIV-1 multiplication (Balasubramanyam et al., 2004).

Antiprotozoan activity

It has been reported that the ethanol extract of the rhizomes has anti-*Entamoeba histolytica* activity and anti-*Leishmania* activity *in vitro* (Koide et al., 2002). Several synthetic derivatives of curcumin showed Anti-*Plasmodium falciparum* effects, anti-*L*. *major* effects (Rasmussen et al., 2000) and anti-*L*. *amazonensis* effects (Gomes et al., 2002).

Antidepressant properties and effect on nervous system

A study has been reported that rats suffering from the chronic mild stress (CMS) have a considerably lower consumption of sucrose, increased interleukin (IL-6), tumour necrosis factor alpha (TNF-α) levels, Corticotropin releasing factor (CRF), and cortisol levels. Ethanolic extract of turmeric causes to increase the sucrose intake to normal control levels, increase in serum IL-6 and TNF-α level and reduced the CRF levels (Yu et al., 2002). Ethanolic extracts of *C. longa* causes to reverse the decrease in some neurotransmitters concentrations as well as the increase in serotonin turnover, cortisol levels and serum corticotrophin-releasing factor (Xia et al., 2007). According to Xu et al., 2006, curcumin exhibited antidepressant activity on behavior in a long-lasting stress rats instead of imipramine, which was the control in the study. A study on Alzheimer's disease (AD) has been shown a direct effect of curcumin in decreasing the amyloid pathology (Ringman et al., 2005).

Anti‐asthmatic activity and smooth muscle relaxant activity

The hydroalcoholic extract of *C. caesia* showed relaxant effect in Guinea pig trachea and study revealed that the extract has receptor antagonists and enzyme inhibitors (Arulmozhi et al., 2006). The *Curcuma caesia* extract concentration dependently relaxed the carbachol (1 µM) -induced pre‐contractions. Methanolic *C. caesia* extract was studied on the histamine aerosol induced bronchospasm and pre‐convulsion dyspnoea in guinea pigs showed significant protection against histamine-induced bronchospasm (Paliwal et al., 2011).

Analgesic activity

Analgesic and antipyretic activity of extracts obtained from *C. caesia* and *C. amada* rhizomes were evaluated by chemical model of acute pain and brewer's yeast induced hyperthermia in rats. Both plants exerted analgesic and antipyretic activity while *C.amada* showed better response than *Curcuma caesia* (Baghel et al., 2013).

Anthelmintic activity

Rhizomes of *C. amada* and *C. caesia with* four extracts viz; Petroleum ether, Dichloromethane, ethanol and aqueous extract were investigated for anthelmintic activity at three different concentrations (50 mg/ml, 100 mg/ml and 150 mg/ml). The results suggested that ethanol extract (150 mg/ml) of *C. caesia* was most effective in causing paralysis of earthworms, while the ethanol extract (150 mg/ml) and Dichloromethane extract (150 mg/ml) of both *Curcuma* species were very effective in causing death of earthworms (Gill et al., 2011).

Effect on gastrointestinal system

Turmeric powder act as gastroprotectant against irritants

while increasing mucin secretion in rabbits (Lee et al., 2003). Anti-ulcer (Uemura et al., 2001), ulcerogenic activities and antiflatulent activity in *in vivo* and *in vitro* experiments in rats also has been reported. Curcumin increases the intestinal lipase, sucrose, and maltase activity (Su et al., 2017). Curcumin also suppresses the intestinal fibrosis (Lin et al., 2006). Moreover, it has been reported that curcumin has significant effect on dyspepsia and gastric Ulcer and a study showed defensive effects of male Sprague–Dawley (pylorus-ligated) rats treated with curcumin (Kim et al., 2005). Ethanolic extracts of *Curcuma* are believed to inhibit gastric acid, gastric juice secretion, and ulcer formation (Rafatullah et al., 1990). Curcumin shows protective activity in cultured rat hepatocytes against carbon tetrachloride, D-galactosamine, peroxide and ionophore-induced toxicity (Kang et al., 2002). Both curcumin and essential oil of *C. longa* showed increased bile production in dogs (Jentzsch et al., 1959) and increases the activity of pancreatic lipase, amylase, trypsin and chymotrypsin (Platel et al., 2000). 1-phenyl-1-hydroxy-*n*-pentane of *C. longa* increases plasma secretion and bicarbonate levels (Chey et al., 1983).

Effect on cardiovascular system

Curcumin increases the possibility of pharmacological interventions to correct the defective Ca^{2+} homeostasis in the cardiac muscle by Ca^{2+}-transport and its slippage from the cardiac muscle sarcoplasmic reticulum (Sumbilla et al., 2002). Curcumin also has been reported a significant hypocholesteremic effect in hypercholesteremic rats (Shafreen et al., 2018).

Effect on nervous system

Curcumins and manganese complexs of curcumin extracted from *Curcuma* plants offer protective action against vascular dementia (Thiyagarajan and Sharma, 2004).

Effect on lipid metabolism

In vivo interaction between curcumin and *α*-tocopherol that may increase the bioavailability of vitamin E and decrease cholesterol levels by significantly reducing low density lipoprotein and very low-density lipoprotein in plasma and total cholesterol level in liver along with an increment of *α*-tocopherol level in rat plasma (Kamal-Eldin et al., 2000). Treatments with curcumin also leads to decrease the ethanol-induced liver damage of humans (Akrishnan et al., 2001).

Wound healing activity

Powdered rhizome, topical application of rhizome extracts and cream formulations of *Curcuma aromatica* exhibited wound healing activity in excision wound models of rabbits (Kumar et al., 2009).

Other uses of genus *Curcuma*

Curcumin has been recognized and used worldwide in many different forms due to its other multiple potential benefits except pharmacological actions. For example, in India and Sri Lanka, turmeric is used in curries; in Japan, it is served in tea; in Thailand, it is used in cosmetics; in China, it is used as a colorant. In addition, in Korea, it is served in drinks; in Malaysia, it is used as an antiseptic; and in the United States, it is used in mustard sauce, cheese, butter, and chips, as a preservative and a coloring agent (Gupta et al., 2013).

***Curcuma* as a natural dye**

People used *Curcuma* species as natural dyes in cosmetics, food (Padhi, 2012), textile materials leather and in medicine (Nattadon et al., 2012). Curcumin, the only natural pigment extracted from the fresh or dried rhizomes of turmeric is historic one of the most famous and the brightest of naturally occurring yellow dyes. It is capable of directly dyeing silk, wool and cotton. Turmeric variety and maturity determine the curcuminoid content, which responsible for color. Harvesting at the correct maturity is an important factor for optimum colour (Aisha et al., 2018). The dye is found to have good saturation and rubbing fastness on cotton (Reazuddin et al., 2017).

Insecticidal effect

It has been found that the compound *ar*-turmerone of *Curcuma* could be used as a low-cost botanical insecticide for integrated management of cabbage looper in vegetable production (Abbott, 1925). The rhizome extract of *Curcuma longa* was found stronger on dose mortality action against *Tribolium castaneum* adults than the aerial part extract (Talukder and Howse, 1993). Termite (*Reticulitermes flavipes)* (Kollar) was exposed to different solvent extracts of turmeric to investigate potential termiticidal properties showed that termiticidal components of turmeric are extractable as a blend containing mainly *ar*-turmerone, turmerone, and curlone (Alshehry et al., 2014). Turmeric is toxic to the maize weevil (*Sitophilus zeamais*) and the fall armyworm (*Spodoptera frugiperda)* and essential oil extracts from turmeric leaf are toxic against *Sitophilus oryzae* L., *Rhyzopertha dominica* and *Tribolium castaneum* (Tavaresa et al., 2013).

Repellent activity

C. aromatica extracts showed repellence against *Aedes*

togoi and provided biting protection for 3.5 h when applied at a concentration of 25%. Further studies on *Curcuma* extracts have reported protective effects against *Armigeres subalbatus, Culex quinquefasciatus,* and *Cx. Tritaeniorhynchus* (Pitasawat et al*.,* 2003). Crude rhizome extracts and volatile oils of *C. aromatica* were evaluated for anti-mosquito potential, including larvicidal, adulticidal, and repellent activities against the *Aedes aegypti* mosquito proved that volatile oils of *Curcuma* possessed a significantly higher larvicidal activity against the 4th instar larvae of *Aedes aegypti* (Kojima et al*.,* 1998).

CONCLUSION

According to the review, genus *Curcuma* is an important medicinal plant with several lead molecules, which are responsible for numerous bioactivities as well as other uses. Hence, isolation and identification of those important molecules are needed for opening of new window in therapeutics. Although there are many *Curcuma* species, chemical constituents and bioactivities and other uses have been investigated only for few commonly used species. In addition, there is limited literature available for studies related to food value, nutritional composition, and health benefits of the edible *Curcuma* species. Further research on nutritional values along with pharmacological studies of uninvestigated and novel compounds is desirable. This will provide immense opportunities for the development of new plant-based food and pharmaceutical products. Moreover, there is no systematic method to differentiate the species within the genera. Even though many species have been identified in India, other countries have not paid much attention to identify *Curcuma* species within their countries and phytochemical or pharmacological investigations. Therefore, researchers have vast field of research to be discovered than what exists presently on medicinally important *Curcuma* species, which will be more useful in therapeutic alternatives to treat many diseases as well as other ecological remedies.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEGMENT

The authors appreciate Research Grants of Uva Wellassa University for funding this research.

REFERENCES

Abbott WS (1925). A method of computing the effectiveness of an insecticide. Journal of Economic Entomology 18:265-267. https://doi.org/10.1093/jee/18.2.265a

Abdel-Lateef E, Mahmoud F, Hammam O, El-Ahwany E, El-Wakil E, Kandil S, Taleb HA, El-Sayed M, Hassenein H (2016). Bioactive Chemical Constituents of *Curcuma longa* L. Rhizomes Extract Inhibit the Growth of Human Hepatoma Cell Line (Hepg2). Acta Pharmaceutica 66:387-398. http://dx.doi.org/10.1515/acph-2016-0028

Aisha R, Abdur R, Waleed K, Faiza S, Abdul B, Hafiz SM, Kashif I, Munir A (2018). Simultaneous dyeing and anti-bacterial finishing on 100% cotton fabric: process establishment and characterization. Cellulose 25(9):5405-5414. http://dx.doi.org/10.1007/s10570-018-1934-9

Akarchariya N, Sirilun S, Julsrigival J, Chansakaowa S (2017). Chemical profiling and antimicrobial activity of essential oil from *Curcuma aeruginosa* Roxb., *Curcuma glans* K. Larsen & J. Mood and *Curcuma xanthorrhiza* Roxb. collected in Thailand. Asian Pacific Journal of Tropical Biomedicine 7:881-885. http://dx.doi.org/10.1016/j.apjtb.2017.09.009

Akrishnan VR, Menon VP (2001). Potential role of antioxidants during ethanol-induced changes in the fatty acid composition and arachidonic acid metabolites in male Wistar rats. Cell Biology and Toxicology 17:11-22.

Alshehry AZ, Zaitoun AA, Abo-Hassan RA (2014). Insecticidal activities of some plant extracts against subterranean termites, *Psammotermes hybostoma* (Desneux) (Isoptera: Rhinotermitidae) International Journal of Agricultural Science 4:257-260.

Anandaraj M, Prasath D, Kandiannan, John ZKT, Srinivasan V, Jha AK, Singh BK, Singh AK, Pandey VP, Singh SP, Shoba N, Jana JC, Ravindra KK, Uma MK (2014). Genotype by environmental interaction effects on yield and curcumin. Industrial Crops and Products53:358-364. http://dx.doi.org/10.1016/j.indcrop.2014.01.005

Angel GR, Menon N, Vimala B, Nambisan B (2014). Essential Oil Composition of Eight Starchy *Curcuma* Species. Industrial Crops and Products 60:233-238. https://dx.doi.org/10.1016/j.indcrop.2014.06.028

Anjusha S, Gangaprasad A (2014). Phytochemical and Antibacterial Analysis of Two Important *Curcuma* Species, *Curcuma aromatica* Salisb. And *Curcuma Xanthorrhiza* Roxb. (Zingiberaceae). Journal of Pharmacognosy and Phytochemistry 3(3):50-53.

Arulmozhi DK, Sridhar N, Veeranjaneyulu A, Arora SK (2006). Preliminary mechanistic studies on the smooth muscle relaxant effect of hydroalcoholic extract of *Curcuma caesia*. Journal of Herbal Pharmacotherapy 6:117-124.

Arun N, Nalini N (2002). Efficacy of turmeric on blood sugar and polyol pathway in diabetic albino rats. Plant Foods for Human Nutrition. 57:41-52.

Baghel SS, Baghel RS, Sharma K, Sikarwar I (2013). Pharmacological activities of *Curcuma caesia*. International Journal of Green Pharmacy 7:1-5. http://dx.doi.org/10.4103/0973-8258.111590

Balasubramanyam K, Varier RA, Altaf M, Swaminathan V, Siddappa NB, Ranga U, Tapas KK (2004). Curcumin, a novel p300/CREB-binding protein specific inhibitor of acetyltransferase, represses the acetylation of histone/nonhistone proteins and histone acetyltransferase-dependent chromatin transcription. Journal of Biological Chemistry 279:51163-51171. http://dx.doi.org/0.1074/jbc.M409024200

Bhavani STN, Sreenivasa MV (1979). Effect of turmeric (*Curcuma longa*) fractions on the growth of some intestinal and pathogenic bacteria *in vitro*. Indian Journal of Experimental Biology 17:1363-1366.

Chen CC, Chen Y, His YT, Chang CS, Huang LF, Ho CT, Way TD, Kao JY (2013). Chemical constituents and anticancer activity of *Curcuma zedoaria* Roscoe essential oil against non-small cell lung carcinoma cells *in vitro* and *in vivo*. Journal of Agricultural and Food Chemistry 61(47):11418-11427.

Chey WY, Millikan L, Lee KY, Watanabe S, Shiratori K, Takeuchi T (1983). Effect of 1-phenylpentanol on release of secretin and exocrine pancreatic secretion in dogs and humans. Gastroenterology 84:1578-1584.

Choudhury SN, Ghosh AC, Saika M, Choudhury M, Leclercq PA (1996). Volatile oil constituents of the aerial and underground parts of *Curcuma aromatica* Salisb. from India. Journal of Essential Oil Research 8:635-638.

Chowdhury H, Banerjee T, Walia S (2008). *In vitro* screening of *Curcuma longa* L and its derivatives as antifungal agents against *Helmintho sporrumoryzae* and *Fusarium solani.* Journal of Pesticide Science 20:6-9.

Cuellar MJ, Giner RM, Recio MC, Just MJ, Manez S, Cerda S, Rios JL (1998). Screening of anti-inflammatory medicinal plants used in traditional medicine against skin diseases. Phytotherapy Research12:18-23.

Dairaku I, Han YN, Yanaka N, Kato N (2010). Inhibitory effect of curcumin on IMP dehydrogenase, the target for anticancer and antiviral chemotherapy agents. Bioscience, Biotechnology and Biochemistry 74:185-187.

Da Silva JKR, Maia JGS, Dosoky NS, Setzer WN (2016). Antioxidant, antimicrobial, and cytotoxic properties of *Aniba parviflora* essential oils from the Amazon. Natural Product Communications 11:1025-1028.

Deeb D, Xu YX, Jiang H, Gao X, Janakiram N, Chapman RA, Gautam SC (2003). Curcumin (diferuloyl-methane) enhances tumor necrosis factor-related apoptosis-inducing ligand-induced apoptosis in LNCaP prostate cancer cells. Molecular Cancer Therapeutics 2:95-103.

Devi NB, Singh PK, Das AK (2014). Ethnomedicinal Utilization of Zingiberaceae in the Valley Districts of Manipur. IOSR Journal of Environmental Science, Toxicology and Food Technology 8(2):21-23.

Dung NX, Truong PX, Ky PT, Leclercq PA (1996). Chemical composition of the essential oils of *Curcuma cochinchinensis* Gagnep. From Vietnam. ACGC Chemical Research Communications 5:11-16.

Dung NX, Truong PX, Ky PT, Leclercq PA (1997). Volatile Constituents of the Leaf, Stem, Rhizome, Roof and Flower Oils of *Curcuma harmandii* Gagnep. from Vietnam. Journal of Essential Oil Research 9:677-681.

Dung NX, Tuyet NTB, Van Khien P, Barthel, Leclercq PA (1998). Characterization of the Leaf Oil of *Curcuma aureginosa* Roxb. from Vietnam. Journal of Essential Oil Research 10:527-528.

Fagodia SK, Singh HP, Batish DR, Kohli RK (2017). Phytotoxicity and cytotoxicity of *Citrus aurantiifolia* essential oil and its major constituents: Limonene and citral. Industrial Crops and Products 108:708-715.

Faiz HC, Al-Amin M, Rahman KM, Sarker A, Alam MM, Chowdhury MH, Khan SN, Sultana GN (2015). Analgesic Principle from *Curcuma Amada*. Journal of Ethnopharmacology 163:273-277.

Fouad HA, Da Camara CAG (2017). Chemical composition and bioactivity of peel oils from *Citrus aurantiifolia* and *Citrus reticulata* and enantiomers of their major constituent against *Sitophilus zeamais* (Coleoptera: Curculionidae). Journal of Stored Products Research. 73:30-36.

Garg SK (1974). Effect of *Curcuma longa* (rhizomes) on fertility in experimental animals. Planta Medica. 26:225-227.

Gill R, Kalsi V, Singh A (2011). Phytochemical investigation and evaluation of anthelmintic activity of *Curcuma amada* and *Curcuma caesia*‐a comparative study. Inventi Impact: Ethnopharmacology. Article ID‐Inventi: ep/412/11, Available from: http:// www.inventi.in/Article/ep/412/11.aspx.

Gomes DC, Alegrio LV, De Lima ME, Leon LL, Araujo CA (2002). Synthetic derivatives of curcumin and their activity against *Leishmania amazonensis*. Arzneimittel-Forschung 52:120-124.

Grieve M (1971). A Modern Herbal: The Medicinal, Culinary, Cosmetic and Economic Properties, Cultivation and Folk-lore of Herbs, Grasses, Fungi, Shrubs, and Trees with All Their Modern Scientific Uses (Volume 2 of Modern Herbal), Courier Corporation. ISBN 0486227995, 9780486227993.

Gupta SC, Patchva S, Aggarwal BB (2013). Therapeutic Roles of Curcumin: Lessons Learned from Clinical Trials. The AAPS Journal15:195-218. http://dx.doi.org/10.1208/s12248-012-9432-8.

Hamss R, Analla M, Campos-Sanchez J, Alonso-Moraga A, Munoz-Serrano A, Idaomar MA (1999). Dose dependent anti-genotoxic effect of turmeric. Mutation Research 446:135-39.

Huxley A (1992). The New RHS Dictionary of Gardening; MacMillan Press: Great Britain.

Jagtap S (2015). Phytochemical Screening, Anti-Oxidant Activity, Multi-Elemental Analysis by ICP- Spectroscopy and Antimicrobial Activity of Rhizome Extracts of *Curcuma pseudomontana* J. Graham. European Journal of Biomedical and Pharmaceutical Sciences 2(4):1152-1169.

Jana NR, Dikshit P, Goswami A, Nukina N (2004). Inhibition of proteasomal function by curcumin induces apoptosis through mitochondrial pathway. Journal of Biological Chemistry 279:11680-1685.

Jantan I, Raweh SM, Sirat HM, Jamil S, Mohd Yasin YH, Jalil J Jamia Azdina (2008). Inhibitory effect of compounds from Zingiberaceae species on human platelet aggregation. Phytomedicine 15(4):306-309.

Jena S, Ray A, Banerjee A, Sahoo A, Nasim N, Sahoo S, Kar B, Patnaik J, Panda JC, Nayak S (2017). Chemical Composition and Antioxidant Activity of Essential Oil from Leaves and Rhizomes of *Curcuma angustifolia* Roxb. Natural Product Research 9:1-4.

Jentzsch K, Gonda T, Holler H (1959). Paper chromatographic and pharmacological investigations on *Curcuma* pigments. Pharm. Helvetica Chimica Acta 34:181-188.

Jeon WY, Lee MY, Shin IS, Jin SE, Ha H (2015). *Curcuma aromatica* Water Extract Attenuates Ethanol- Induced Gastritis via Enhancement of Antioxidant Status. Evidence-Based Complementary and Alternative Medicine 582496.http://dx.doi.org/10.1155/2015/582496

Jose S, Thomas TD (2014). Comparative Phytochemical and Anti-Bacterial Studies of Two Indigenous Medicinal Plants *Curcuma caesia* Roxb. And *Curcuma aeruginosa* Roxb. International Journal of Green Pharmacy 8:65-71.

Kamal-Eldin A, Frank J, Razdan A, Tengblad S, Basu S, Vessby B (2000). Effects of dietary phenolic compounds on tocopherol, cholesterol, and fatty acids in rats. Lipids 35:427-435.

Kamazeri TSAT, Samah OA, Taher M, Susanti D, Qaralleh H (2012). Antimicrobial Activity and Essential Oils of *Curcuma aeruginosa, Curcuma mangga* and *Zingiber cassumunar* from Malaysia. Asian Pacific Journal of Tropical Medicine 5(3):202-209.

Kang HC, Ji-Xing N, Pil-Hoon P, Ji-Young K, Sung HL, Sun WW, Yu-Zhe Z, Eun-Jeon P, Dong HS (2002). Curcumin inhibits collagen synthesis and hepatic stellate cell activation *in vivo* and *in vitro*. Journal of pharmacy and pharmacology 54(1):119-126.

Kim DC, Kim SH, Choi BH, Baek NI, Daeho Kim, Kim MJ, Kim KT (2005). *Curcuma longa* extract protects against gastric ulcers by blocking H2 histamine receptors. Biological and Pharmaceutical Bulletin 28:2220-2224.

Kim DSHL, Kim JY, Han YS (2007). Alzheimer's Disease Drug Discovery from Herbs: Neuroprotectivity from Beta-Amyloid (1-42) Insult. The Journal of Alternative and Complementary Medicine 13(3):333-340.

Kim MK, Choi GJ, Lee HS (2003). Fungicidal property of *Curcuma longa* L. Rhizome-derived curcumin against phytopathogenic fungi in a greenhouse. Journal of Agricultural and Food Chemistry 51:1578-81.

Koide T, Nose M, Ogihara Y, Yabu Y, Ohta N (2002). Leishmanicidal effect of curcumin *in vitro*. Biological and Pharmaceutical Bulletin 25:131-133.

Kojima H, Yanai T, Toyota A (1998). Essential oil constituents from Japanese and Indian *Curcuma aromatica* rhizomes. Planta Medica 64(4):380-381.

Kress WJ, Prince LM, Williams KJ (2002). The phylogeny and a new classification of the gingers (Zingiberaceae): evidence from molecular data. American Journal of Botany 89:1982-1696.

Kumar A, Chomwal R, Kumar P, Renu S (2009). Antiinflammatory and wound healing activity of *Curcuma aromatica* salisb extract and its formulation. Journal of Chemical and Pharmaceutical Research 1(1):304-10.

Kumar S, Narain U, Tripathi S, Misra K (2001). Synthesis of curcumin bioconjugates and study of their antibacterial activities against beta-lactamase-producing microorganisms. Bioconjugate Chemistry 12:464-469.

Kutti GD, Lingamallu J (2012). Comparison of chemical composition and antioxidant potential of volatile oil from fresh, dried and cured turmeric (*Curcuma longa*) rhizomes. Industrial Crops and Products 38:124-131.

Lai EYC, Chyau CC, Mau JL, Chen CC (2004). Antimicrobial Activity and Cytotoxicity of the Essential Oil of *Curcuma zedoaria.* The

American Journal of Chinese Medicine 32:281.
Lechtenberg M, Quandt B, Nahrstedt A (2004). Quantitative determination of curcuminoids in *Curcuma* rhizomes and rapid differentiation of *Curcuma domestica* Val. and *Curcuma zanthorrhiza* Roxb. by capillary electrophoresis. Phytochemical Analysis15:152-158.
Lee CJ, Lee JH, Seok JH, Hur GM, Park YC, Seol IC, et al. (2003). Effects of baicalein, berberine, curcumin and hespiridin on mucin release from airway goblet cells. Planta Medica 69:523-526.
Liao S, Lin J, Dang MT, Zhang H, Kao YH, Fukuchi J, Hiipakka RA (2001). Growth suppression of hamster flank organs by topical application of catechins, alizarin, curcumin, and myristoleic acid. Archives of Dermatological Research 293:200-205.
Li CJ, Zhang LJ, Dezube BJ, Crumpacker CS, Pardee AB (1993). Three inhibitors of Type 1 human immunodeficiency virus long terminal repeat-directed gene expression and virus replication. Proceedings of the National Academy of Sciences of the United States of America 90:1839-1842.
Li J, Bian WH, Wan J, Zhou J, Lin Y, Wang JR, Wang ZX, Shen Q, Wang KM (2014). Curdione inhibits proliferation of MCF-7 cells by inducing apoptosis. Asian Pacific Journal of Cancer Prevention 15:9997-10001.
Lin X, Xue L, Zhang H, Zhu C (2006). Determination of curcumins in turmeric by micellarelectro kinetic capillary chromatography. Canadian Journal of Analytical Sciences and Spectroscopy 51:35-42.
Lin YG, Kunnumakkara AB, Nair A, Merritt WM, Han LY, Armaiz-Pena GN, Kamat AA, Spannuth WA, Gershenson DM, Lutgendorf SK, Aggarwal BB, Sood AK (2007). Curcumin inhibits tumor growth and angiogenesis in ovarian carcinoma by targeting the nuclear factor-_B pathway. Clinical Cancer Research 13:3423-3430.
Liu B, Gao YQ, Wang XM, Wang YC, Fu LQ (2014). Germacrone inhibits the proliferation of glioma cells by promoting apoptosis and inducing cell cycle arrest. Mol Med Rep 10(2): 1046-1050.
Liu N, Wu TL (1999). Notes on *Curcuma* in China. Journal of Tropical and Subtropical Botany 7:146-150.
Maciel N, Criley RA (2003). Morphology, growth and flowering behavior of *Curcuma zedoaria.* Acta Horticulturae (ISHS) 624:111-116.
Mahady GB, Pendland SL, Yun G, Lu ZZ (2002). Turmeric (*Curcuma longa*) and curcumin inhibit the growth of *Helicobacter pylori*, of group 1 carcinogen. Anticancer Research 22:4179-4181.
Maikhuri RK, Gangwar AK (1993). Ethnobiological notes on the Khasi and Garo tribes of Meghalaya, Northeast India. Economic Botany47:345-357.
Malek SN, Seng CK, Zakaria Z, Ali NA, Ibrahim H, Jalil MN (2006). The Essential Oil of *Curcuma inodora* aff. Blatter from Malaysia. Journal of Essential Oil Research 18(1):281-283.
Marina GD, Kekuda PTR, Sudarshan SJ (2008). Antitussive activity of ethanolic extract of *Curcuma aromatica* rhizomes on sulfur dioxide induced cough in miceAncient Science of Life 27(3):36-40.
Martin-Cordero C, Lopez-Lazaro M, Galvez M, Ayuso MJ (2003). Curcumin as a DNA topoisomerase II poison. Journal of Enzyme Inhibition and Medicinal Chemistry18:505-509.
Martins CV, Da Silva DL, Neres AT, Magalhães TF, Watanabe GA, Modolo LV, Sabino AA, De Fátima A, De Resende MA (2009). Curcumin as a promising antifungal of clinical interest. Journal of Antimicrobial Chemotherapy 63:337-339.
Menon VP, Sudheer AR (2007). Antioxidant and anti-inflammatory properties of curcumin. Advances in Experimental Medicine and Biology 595:105-125.
Nattadon R, Ungruangkitkrai R, Attanaphol M, Ongkholrattanasit (2012). EcoFriendly of Textiles Dyeing and Printing with Natural Dyes. International Conference, Textiles & Fashion, July 34, 2012, Bangkok Thailand.
Newman MF, Lhuillier A, Poulsen ADA (2004). Checklist of the Zingiberaceae of Malaysia. Blume 16:63. ISBN 90-71236-XX-X
Nishiyama T, Mae T, Kishida H, Tsukagawa M, Mimaki Y, Kuroda M, Kuroda M, Sashida Y, Takahashi K, Kawada T, Nakagawa K, Kitahara M (2005). Curcuminoids and sesquiterpenoids in turmeric (*Curcuma longa* L.) suppress an increase in blood glucose level in Type 2 diabetic KK-Ay mice. Journal of Agricultural and Food Chemistry 53:959-963.
Nithya R, Jaysshree N (2017). A review on herbs of the Zingiberaceae family with beneficial effects on cardiovascular diseases. World Journal of Pharmacy and Pharmaceutical Sciences 6(6):635-643.
Noura SD, William NS (2018). Chemical Composition and Biological Activities of Essential Oils of *Curcuma* Species, Nutrients 10:1196.
Nwozo SO, Osunmadewa DA, Oyinloye BE (2014). Anti-fatty liver effects of oils from *Zingiber officinale* and *Curcuma longa* on ethanol-induced fatty liver in rats. Journal of Integrative Medicine 12:59- 65.
Oon SF, Nallappan M, Tee TT, Shohaimi S, Kassim NK, Sa'ariwijaya MSF, Cheah YH (2015). Xanthorrhizol: A review of its pharmacological activities and anticancer properties. Cancer Cell International 15:100.
Paisooksantivatana Y, Thepsen O (2001). Phenetic relationships of some Thai *Curcuma* species (Zingiberaceae) based on morphological, palynological and cytological evidences. Thai Journal of Agricultural Science 34:47-57.
Paliwal P, Pancholi SS, Patel RK (2011). Pharmacognostic Parameters for Evaluation of the Rhizomes of *Curcuma caesia*. Journal of Advanced Pharmaceutical Technology and Research 2:56-61.
Panahi Y, Alishiri GH, Parvin S, Sahebkar A (2016a). Mitigation of systemic oxidative stress by curcuminoids in osteoarthritis: Results of a randomized controlled trial. Journal of Dietary Supplements 13:209-220.
Panahi Y, Hosseini MS, Khalili N, Naimi E, Simental-Mendia LE, Majeed M, Sahebkar A (2016b). Effects of curcumin on serum cytokine concentrations in subjects with metabolic syndrome: A post-hoc analysis of a randomized controlled trial. Biomedicine & Pharmacotherapy 82:578–582.
Pandey AK, Chowdhury AR (2003). Volatile Constituents of the Rhizome Oil of *Curcuma caesia* Roxb. From Central India. Flavour and Fragrance Journal 18:463-468. https://doi.org/10.1002/ffj.1255
Panich U, Kongtaphan K, Onkoksoong T, Jaemsak K, Phadungrakwittaya R, Thaworn A, Pravit A, Adisak W (2010). Modulation of antioxidant defense by *Alpinia galanga* and *Curcuma aromatica* extracts correlates with their inhibition of UVA-induced melanogenesis. Cell Biology and Toxicology 26(2):103-116.
Pant M, Misra H, Jain DC (2013). Phytochemical Investigation of Ethyl Acetate Extract from *Curcuma aromatica* Salisb. Rhizomes. Arabian Journal of Chemistry 6:279-283.
Pawar RK, Sharma S, Singh KC, Sharma Rajeev KR (2011). Development and validation of HPTLC method for the determination of andrographolide in kalmegh navayas lohaan ayurvedic formulation. International Journal of Pharmacy and Pharmaceutical Sciences 3:975-1491.
Pemba HB, Sharangi AB (2017). Promising curcuma species suitable for Hill regions towards maintaining biodiversity. Journal of Pharmacognosy and Phytochemistry 6(6):726-731.
Pitasawat B, Choochote W, Tuetun B, Tippawangkosol P, Kanjanapothi D, Jitpakdi A, Duangrat R (2003). Repellency of aromatic turmeric *Curcuma aromatica* under laboratory and field conditions. Journal of Vector Ecology 28(2):234-240.
Platel K, Srinivasan K (2000). Influence of dietary spices and their active principles on pancreatic digestive enzymes in albino rats. Nahrung 44:42-46.
Policegoudra RS, Rehna K, Rao LJ, Aradhya SM (2010). Antimicrobial, Antioxidant, Cytotoxicity and Platelet Aggregation Inhibitory Activity of a Novel Molecule Isolated and Characterized from Mango Ginger (*Curcuma amada* Roxb.) Rhizome. Journal of Biosciences 35(2):231-240.
Priyadarsini KI, Maity DK, Naik GH, Kumar MS, Unnikrishnan MK, Satav JG, Mohan H (2003). Role of phenolic O-H and methylene hydrogen on the free radical reactions and antioxidant activity of curcumin. Free Radical Biology and Medicine 35:475-484.
Prucksunand C, Indrasukhsri B, Leethochawalit M, Hungspreugs K (2001). Phase II clinical trial on effect of the long turmeric (*Curcuma longa* Linn) on healing of peptic ulcer. The Southeast Asian Journal of Tropical Medicine and Public Health 32:208-215.
Pukhrambam C (2002). Evaluation of Antioxidant Properties in Some Members of Zingiberales and Micropropagation of Elites. Ph.D Thesis, Manipur University, Imphal, 2002.
Purkayastha J, Nath SC, Klinkby N (2006). Essential oil of the rhizome of *Curcuma zedoaria* (Christm.) Rosc. native to northeast India. Journal of Essential Oil Research18:154-155.

Rafatullah S, Tariq M, Al-Yahya MA, Mossa JS, Ageel AM (1990). Evaluation of turmeric (*Curcuma longa*) for gastric and duodenal antiulcer activity in rats. Journal of Ethnopharmacology 29:25-34.
Rajashekhara N, Sharma PP (2010). A Comparative Study of Efficacy of Tugaksheeree (*Curcuma angustifolia* Roxb. and *Maranta Arundinacea* Linn. In Management of Amlapitta, Ayurveda 31(4):482-486.
Ramasree AB, Indira B (2006). Anatomical and histochemical studies on four species of Curcuma. Phytomorphology 56:1-8.
Rao AS, Bandaru R, Ramachandran S (1989). Volatile Aroma Components of *Curcuma amada* Roxb. Journal of Agricultural and Food Chemistry 37:740-743.
Rasmussen HB, Christensen SB, Kuist LP, Karazmi A (2000). A simple and effective separation of the curcumins, the antiprotozoal constituents of *Curcuma longa*. Planta Medica 66:396-398.
Padhi BS (2012). Pollution due to synthetic dyes toxicity and carcinogenicity studies and remediation. International Journal of Environmental Sciences 3:940.
Raut JS, Karuppayil SM (2014). A status review on the medicinal properties of essential oils. Industrial Crops and Products 62:250-264.
Ravindran PN, Babu KN, Shiva KN (2007). Botany and crop improvement of tumeric. In Turmeric the Genus *Curcuma*; CRC Press: Boca Raton, FL, USA pp. 15-70.
Reazuddin R, Tauhidul IM, Abdullah AM (2017). Ecological risk assessment and health safety speculation during color fastness properties enhancement of natural dyed cotton through metallic mordants. Fashion and Textiles 4:1.
Ringman JM, Frautschy SA, Cole GM, Masterman DL, Cummings JL (2005). A potential role of the curry spice curcumin in Alzheimer's disease. Current Alzheimer Research 2:131-136.
Rithaporn T., Monga M, Rajasekharan M (2003). Curcumin: a potential vaginal contraceptive. Contraception 68:219-223.
Roshan PY, Gaur T (2017). Versatility of turmeric: A review the golden spice of life. Journal of Pharmacognosy and Phytochemistry 6(1):41-46.
Sahdeo P, Bharat BA (2011). Turmeric, the golden spice: from traditional medicine to modern medicine. In: Herbal Medicine: Biomolecular and Clinical Aspects. Benzie IFF, Wachtel-Galor S, editors. Boca Raton Fl., CRC Press Taylor and Francis 2011 Chapter 13.
Sahebkar A, Serbanc MC, Ursoniuc S, Banach M (2015). Effect of curcuminoids on oxidative stress: A systematic review and meta-analysis of randomized controlled trials. Journal of Functional Foods 18:898-909.
Saikia B, Borthakur SK (2010). Use of Medicinal Plants in Animal Healthcare- A Case Study from Gohpur, Assam, Indian Journal of Traditional Knowledge 9(1):49-51.
Sanatombi R, Sanatombi K (2017). Nutritional value, phytochemical composition and biological activities of edible *Curcuma* species: A review, International Journal of Food Properties 20(sup3):S2668-S2687. http://dx.doi.org/10.1080/10942912.2017.1387556
Sanghamitra N, Sujata M, Nagar K (2015). Differential effect of soil and environment on metabolic expression of turmeric (*Curcuma longa* cv. Roma). Indian Journal of Experimental Biology 53:406-411.
Sarangthem K, Haokip MJ (2010). Bioactive Components in *Curcuma caesia* Roxb. Grown in Manipur. Bioscan 5:113-115.
Satyendra SB, Rajendra SB, Kshamashil S, Indu S (2013). Pharmacological activities of *Curcuma caesia*. International Journal of Green Pharmacy 7:1-5.
Saxena PN, Anand S, Saxena N, Bajaj P (2009). Effect of arsenic trioxide on renal functions and its modulation by *Curcuma aromatica* leaf extract in albino rat. Journal of Environmental Biology 30(4):527-31.
Shafreen RB, Lubinska M, Ró˙za´ nska A, Dymerski T, Namie´snik J, Katrich E, Gorinstein S (2018). Human serum interactions with phenolic and aroma substances of Kaffir *(Citrus hystrix)* and Key lime (*Citrus aurantifolia*) juices. J. Lumin. https://doi.org/10.1016/j.jlumin.2018.04.010
Sharma A (2012). Traditional Processing of Shotti (*Curcuma angustifolia* Roxb.)- A Rhizome Based Ethnic Weaning Food. Indian Journal of Traditional Knowledge 11(1):154-155.
Sharma GJ, Chirangini P, Kishor R (2011). Gingers of Manipur: Diversity and Potentials as Bioresources. Genetic Resources and Crop Evolution 58:753-767.
Shirgurkar MV, John CK, Nadguada RS (2001). Factors effecting *in vitro* microrhizome production in turmeric. Plant Cell, Tissue and Organ Culture 64:5-11.
Shukla Y, Arora A, Taneja P (2002). Antimutagenic potential of curcumin on chromosomal aberrations in Wistar rats. Mutation Research 515:197-202.
Sikha A, Harini A, Prakash H (2015). Pharmacological activities of wild turmeric (*Curcuma aromatica* Salisb): A review. Journal of Pharmacognosy and Phytochemistry 3:1-4.
Singh G, Kapoor IPS, Singh P, De Heluani CS, De Lampasona MP, Catalan CAN (2010). Comparative study of chemical composition and antioxidant activity of fresh and dry rhizomes of turmeric (*Curcuma longa* Linn.). Food and Chemical Toxicology 48:1026-1031. http://dx.doi.org/10.1016/j.fct.2010.01.015
Singh G, Singh OP, Maurya S (2002). Chemical and Biocidal Investigations on Essential Oils of Some Indian *Curcuma* Species. Progress in Crystal Growth and Characterization of Materials 45:75–81.
Sirirugsa P, Larsen K, Maknoi C (2007). The Genus *Curcuma* L. (Zingiberaceae): Distribution and Classification with Reference to Species Diversity in Thailand. Gardens' Bull. Singapore 59:1-2.
Sirirugsa P (1998). Thai Zingiberaceae: Species Diversity and Their Uses. International Conference on Biodiversity and Bioresources: Conservationand Utilization. Pure and Applied Chemistry 70(11).
Srinivasan V, Thankamani CK, Dinesh R. Kandiannan K, Zachariah TJ, Leela NK, Hamza S, Shajina O, Ansha O (2016). Nutrient management systems in turmeric: Effects on soil quality, rhizome yield and quality. Industrial Crops and Products 85:241-250.
Srivilai J, Waranuch N, Tangsumranjit A, Khorana N, Ingkaninan K (2018). Germacrone and sesquiterpene-enriched extracts from *Curcuma aeruginosa* Roxb. increase skin penetration of minoxidil, a hair growth promoter. Drug Delivery and Translational Research 8:140-149.
Sumbilla C, Lewis D, Hammerschmidt T, Inesi G (2002). The slippage of the Ca2+ pump and its control by anions and curcumin in skeletal and cardiac sarcoplasmic reticulum. Journal of Biological Chemistry 277:13900-13906.
Suryanarayana P, Krishnaswamy K, Reddy GB (2003). Effect of curcumin on galactose-induced cataractogenesis in rats. Molecular Vision 9:223-230.
Su X, Jiang B, Wang H, Shen C, Chen H, Zeng Li (2017). Curcumin suppresses intestinal fibrosis by inhibition of PPARγ-mediated epithelial-mesenchymal transition. Evidence-Based Complementary and Alternative Medicine 92:57-66.
Taher MM, Lammering G, Hershey C, Valerie K (2003). Curcumin inhibits ultraviolet light induced human immunodeficiency virus gene expression. Molecular and Cellular Biochemistry 254:289-97.
Talukder FA, Howse PE (1993). Deterrent and insecticidal effects of extracts of pithraj, *Aphanamixis polystachya* (Meliaceae), against *Tribolium castaueum* in storage. Journal of Chemical Ecology 19:2463-2471. http://dx.doi.org/10.1007/BF00980683
Tavaresa WDS, Freitas SDS, Grazziottib GH, Parentec LML, Lia LM, Zanuncioe JC (2013). Ar-turmerone from *Curcuma longa* rhizomes and effects on *Sitophilus zeamais* and *Spodoptera frugiperda*. Industrial Crops and Products 46:158-164.
Theanphong O, Mingvanish W, Kirdmanee C (2015). Chemical constituents and biological activities of essential oil from *Curcuma aeruginosa* Roxb. rhizome. Bulletin of Science, Technology & Society13:6-16.
Thiyagarajan M, Sharma SS (2004). Neuroprotective effect of curcumin in middle cerebral artery occlusion induced focal cerebral ischemia in rats. Life sciences 74:969-985.
Tsai SY, Huang SJ, Chyau CC, Tsai CH, Weng CC, Mau JL (2011). Composition and antioxidant properties of essential oils from *Curcuma* rhizome. Asian Journal of Applied Sciences 2:57-66.
Tyag DK (2005). Pharma Forestry: A Field Guide to Medicinal Plants; Atlantic Publishers & Distributors: New Delhi, India.
Uemura N, Okamoto S, Yamamoto S, Matsumura N, Yamaguchi S, Yamakido M, Kiyomi T, Naomi S, Ronald JS (2001). *Helicobacter*

pylori infection and the development of gastric cancer. New England Journal of Medicine 13:784-9.
Ungphaiboon S, Supavita T, Singchangchai P, Sungkarak S, Rattanasuwan P, Itharat A (2005). Study on antioxidant and antimicrobial activities of turmeric clear liquid soap for wound treatment of HIV patients. Songklanakarin Journal of Science and Technology 27(2):269-578.
Vairappan CS, Elias UM, Ramachandram TR, Kamada T (2013). Secondary Metabolites from Rhizome of *Curcuma caesia* Roxb. (Zingiberaceae). Biochemical Systematics and Ecology 48:107-110.
Wu WY, Xu Q, Shi LC, Zhang WB (2000). Inhibitory effects of *Curcuma aromatica* oil on proliferation of hepatoma in mice. World Journal of Gastroenterology 6(2):216-219.
Xiang H, Zhang L, Lu Xi, Yang Y, Wang X, Lei D, Xi Zheng, Liu X (2018). Phytochemical profiles and bioactivities of essential oils extracted from seven *Curcuma* herbs, Industrial crops and products 111:298-305.
Xiang Z, Wang X, Cai X, Zeng S (2011). Metabolomics Study on Quality Control and Discrimination of Three *Curcuma* Species Based on Gas Chromatograph-Mass Spectrometry. Phytochemical Analysis 22:411-418.
Xia Q, Zhao KZ, Huang ZG, Zhang P, Dong TXX, Li SP, Tsim KWK (2005). Molecular genetic and chemical assessment of Rhizoma Curcumae in China. Journal of agricultural and food chemistry, 53(15):6019-6026. http://dx.doi.org/10.1021/jf0508495
Xia X, Cheng G, Pan Y, Xia ZH, Kong LD (2007). Behavioral, neurochemical and neuroendocrine effects of the ethanolic extract from *Curcuma longa* L. in the mouse forced swimming test. Journal of Ethnopharmacology 110:356-363. http://dx.doi.org/10.1016/j.jep.2006.09.042
Xu Y, Ku B, Tie L, Yao H, Jiang W, Ma X, Li X (2006). Curcumin reverses the effects of chronic stress on behavior, the HPA axis, BDNF expression and phosphorylation of CREB. Brain research 1122(1):56-64. http://dx.doi.org/10.1016/j.brainres.2006.09.009
Yu ZF, Kong LD, Chen Y (2002). Antidepressant activity of aqueous extracts of *Curcuma longa* in mice. Journal of Ethnopharmacology 83:161-165.
Zhang L,Yang Z, Wei J, Su P, Pan W, Zheng X, Zhang K, Lin L, Tang J, Fang, Du Z (2017). Essential oil composition and bioactivity variation in wild-growing populations of *Curcuma phaeocaulis* Valeton collected from China. Industrial Crops and Products103:274-282. http://dx.doi.org/10.1016/j.indcrop.2017.04.019