

PHCOG REV. : Review Article

Phytochemical and Biological Potential of Indrayan: An Overview

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ABSTRACT

Medicinal plants play an imperative role in the management of various diseases especially in the developing countries where resources are meager. Indrayan (*Citrullus Colocynthis* Schard.) has been reported as folk medicine in various countries. It has been traditionally used as an abortifacient and to treat constipation, oedema, bacterial infections, cancer and diabetes. The principal constituents of colocynth include alkaloids, triterpenoids, glycosides and resins which are mainly responsible for its biological activities. Considering the extensive interest and recent progress on the structural and biological activity of active constituents, the present review systematically focuses on the structures and biological activity of the plant.

Keywords: Medicinal plants, Folk Medicine, *Citrullus Colocynthis*, *Cucurbitaceae*, Activity.

INTRODUCTION

Indrayan or Indravaruni is occurring throughout country and belong to family *cucurbitaceae*; it is represented by 100 genera and 850 species, out of them 85 species are found in India. Indrayan consists of dried root, fruit, seeds and leaf of *Citrullus Colocynthis* Schard., family *cucurbitaceae*; an annual or perennial, wild herb with prostrate climbing stem, occurring throughout the country. The different parts of crude drug also known as many synonyms; these are given in Table 1 (1). Colocynth or Bitter apple is found, cultivated and wild, throughout India in warmer areas. It is an extensively trailing annual herb with bifid tendrils angular branching stems and wooly tender shoots. Leaves are deeply divided; lobes narrow thick, glabrous or somewhat hairy. Flowers are unisexual, yellow, both males and females solitary and with pale-yellow corolla. Fruit is a globose or oblong fleshy indehiscent berry, 5 to 7.5 cm in diameter and variegated with green and white. Seeds are pale brown. The fruits are useful in tumours, ascites, leucoderma, ulcers, asthma, bronchitis, urethrorrhea, jaundice, dyspepsia, constipations, elephantiasis, tubercular glands of the neck and splenomegaly. It is useful in abnormal presentations of the foetus and in atrophy of the foetus. In addition to the above properties, the root has a beneficial action in inflammation of the breasts, pain in the joints; externally it is used in ophthalmia and in uterine pains. The fruit and root, with or without is rubbed into a paste with water and applied to boils and pimples. In rheumatism, equal parts of the root and long pepper are given in pill. A paste of the root is applied to the enlarged abdomen of children (2).

The fruit is useful in ascites, biliousness, jaundice, cerebral congestion, colic, constipation dropsy, fever, worms and sciatica. Root is given in cases of abdominal enlargement, cough, asthma, and inflammation of the breast, ulcers, urinary diseases and rheumatism. Oil from seeds is used for poisonous bites, bowel complaints, epilepsy and also for blackening the hair (3). The important formulations using the

root and fruit are *Abbayarista*, *Mahatiktakam kasaya*, *Manasamitravatakam*, *Cavikasava*, *Madhuyastyadi taila*, etc. (4).

The powder is often used as an insecticide. The extract should never be given without some aromatic to correct its griping tendency (5). Fruit contains a glycoside- colocynthin, its aglycone- α -elaterin, citrullin, citrullene and citrullinic acid. Unripe fruit contains p-hydroxy benzyl methyl ester. Roots contain α -elaterin and hentriacontane (6). Colocynth is, in moderate doses, drastic, hydrogogue, cathartic and diuretic. In large doses, it is emetic and gastro-intestinal irritant and in small doses, it is expectorant and alterative. Colocynthin is a cathartic and intensely bitter principle. It has a purgative action. All parts of the plant are very bitter. The fruit has been described as cathartic (7). Many plants belonging to family *cucurbitaceae* are believed to be Indrayan such as *Trichosanthis palamte* (Indrayan red), *Cucurmins trigonus* (Indrayan chhiti) etc. *Citrullus colocynthis* is a desert plant with a rich history as a medicinal plant and as a source of valuable oil. It is small appearing in several early Egyptian, Libyan and Near Eastern sites from about 4000 BC (8). It primarily accumulates citrulline functions as an efficient radical scavenger and thus contributes to oxidative stress-tolerance (9). *Citrullus colocynthis* (L.) schard., also known as bitter cucumber, vine-of-sodom, tumba etc. and also widely distributed in Sahara-Arabian phyto-geographic region in Africa, plant grows abundantly in south of Iran, Sudan, middle ages to Spain and Cyprus and Mediterranean region. The species characterized by its angular and rough stem, deeply 3-7 lobed leaves of 5 to 10 cm and solitary pale yellow flower. Each plant produced 15 to 30 round (7 to 10 cm) fruits, green yellow stripes with small (~ 6 mm) smooth brownish seeds (10). In the traditional medicine of Iran, this plant used to treat constipation, oedema, bacterial infection, cancer, amenorrhea, jaundice, leukemia, rheumatism and tumor. In Sriya, it also used as an insect repellent. A number of plant secondary metabolite including cucurbitacin,

falconoid, caffiec acid derivative and terpenoids has been reported from this plant (11-16).

Colocynthis Citrullus (Melon) is widely cultivated and consumed oil seed crop in West Africa. The seeds popularly called 'egusi' contain about 53% oil, 28% protein and some other mineral nutrients (17-18). They are consumed in "egusi soup", melon ball snacks and ogiri (a fermented condiment) (19-20). Melon seeds contain a fairly high amount of unsaturated fatty acids, linoleic acid (21), they have a hypo-cholesteronic effect. The oil expressed from seeds is used for edible purposes (22) while the residual cake is fried and consumed as a snack.

Table 1: Various Synonyms of different parts of *Citrullus Colocynthis* Schard

Synonyms	Root	Leaf	Fruit
Sanskrit	Indravalli,	Eandri,	Aendri,
	Indravarunika, Endri	Gavaksi	Gavaski
Assam	----	Nantiyah	Gavadani
Bengali	Rakhal Sasa	Rahhalasa,	Rakhal
	Mul	Makhal	
English	Colocynth, Bitter apple	Colocynth, Bitter apple	Colocynth
Gujrati	Indravarana,	Indrayana,	Indrayan
	Indrayana, Indramanoa	Indrayanao, Insbak	
Hindi	Indrayana	Indrayana	Indrayan
Kannada	Havumekke,	Havumekke	Havumekke
	Havumakke, Kadukavadi	Kayi, Havumakke	
	Valiyakattuvell, Valiya	Katu Vellari, Kadu	Kattu Vellarikkai, Valiya
Malyalam	Pekumatti	Indrayan, Peykummuti	Pekumatti
	Marathi	Endrayana, Indravarana	Indravarana, Kadu Indrayan
Punjabi	Kaudatumma, Tumbi	Tumma, Jamtumma	Indrayana
	Tamil	Paikamatti, Varithumatti	Peytumatti, Verittumatti
Telgu	Chedu	Chedu	Chedu
	Puchcha	Puchcha	Puchcha
Urdu	Hanzal,	Hanzal,	Hanjil,
	Indrayan	Indrayan	

PHYTOCHEMICAL REVIEW

The principal of colocynth include bitter, amorphous, alkaloids and resin, these are responsible for its purgative action. The plants contain cucurbitacin A, B, C, D and E (23). The pulp also contains cucurbitacin E (α -claterin) compounds, colocynthin, colocynthidin, phytosterol and fatty acids. Resin, gum and amyloid principle colocynthin ($C_{56}H_{84}O_{23}$), a yellowish, translucent, bitter and friable glucoside, this bitter active glucoside is principal constituents in colocynthis. A group of terpenoids (cucurbitacins) are main constituents of the standardized extract. The natural cucurbitacins constitute a

group of tri-terpenoid substances which are well-known for their bitterness and toxicity. Structurally, they are characterized by the tetracyclic cucurbitane nucleus skeleton, namely, 19-(10 \rightarrow 9b)-abeo-10a-lanost-5-ene (also known as 9b-methyl-19-norlanosta-5-ene), with a variety of oxygen substitutions at different positions. According to the characteristics of their structures, cucurbitacins are divided into twelve categories but we cover only those found in *Citrullus colocynthis* species. Cucurbitacins are noted for their cytotoxic behavior and were a hot topic within the medicinal chemistry and drug discovery community from an anti-cancer drug development perspective, particularly in the 1960's. However, the application potential of cucurbitacins was substantially hindered by their nonspecific cytotoxicity, and therefore, only very limited usage was pursued under strict medical control (24).

Cucurbitacin A (Fig. 1) is not widely distributed, but Cucurbitacin B (Fig. 2) has been found in many Cucurbitaceae species. Cucurbitacin C (Fig. 3) is rare in nature, in contrast to cucurbitacin B, cucurbitacin D (Fig. 4), which lacks the acetyl group at the 25-OH, is the most ubiquitous cucurbitacin known and cucurbitacin E (Fig. 5) found in pulp (24). The pulp was separated from the seeds. The ground pulp (500 g) was macerated in water/methanol (30/70) for 24 hours (three times), and the hydro-methanolic solution was subsequently concentrated by evaporation up to 1/3 of the initial volume. The extract was fractioned by the following solvents with increasing polarity: petroleum ether, chloroform, ethyl acetate, and butanol and water fractions. The fractions were concentrated to dryness by rotary evaporator. The butanol fraction (2 g) was subjected to Sep-Pack (ODS) fractionation using a step gradient of MeOH-water mixture (10:90, 20:80, 40:60, 60:40, 80:20 and 100:0). The preparative reversed-phase HPLC analysis was employed to isolate compounds from the butanol fraction of the hydro-methanolic (70%) extract of the fruits of the locally grown *C. colocynthis*. Three flavone glucosides and two cucurbitacin glucosides; Isoscoparin (Fig. 6); Isovitexin (Fig. 7); Isoorientin 3'-O-methyl ether (Fig. 8); 2-O- β -D-glucopyranosylcucurbitacin I (Fig. 9) and 2-O- β -D-glucopyranosylcucurbitacin E (Fig. 10) of the *C. colocynthis* were isolated and the structures of the isolated compounds were determined by spectroscopic means (25).

The methanolic extract of the fresh fruits was fractionated by different chromatographic techniques, which resulted in the isolation and structure elucidation of a new compound Cucurbitacin glycoside (Fig. 11), along with 2-O- β -D-glucopyranosyl cucurbitacin B (arvenin I, Fig. 12) and 2, 25-di-O- β -D-glucopyranosyl-cucurbitacin L (Fig. 13) which is first time reported (26-28). Equisi (*Citrullus colocynthis* Schard) Kernels contain approximately protein (28.4%), oil (52%), ash (3.6%), fibres (2.7%) and carbohydrate; its oil contains linoleic acid (63%), oleic acid (16%) and small amount linolenic acid. Such oil composition resembles that of safflower oil and is very beneficial in human nutrition (29-32). The methanolic extract of powdered *C. colocynthis* fruits was purified by column chromatographic on Sephadex LH20 to give two fractions, rich in flavonoids. Further purification afforded Isoorientin

3'-*O*-methyl ether (Fig. 8), Isoorientin (Fig. 14), Isovitexin (Fig. 7) (33, 13). The aerial parts were treated similarly on Silica Gel CC and further purification on preparative TLC results three new flavone C-glycosides viz. Hydroxybenzyl Isovitexin (Fig. 15), 6-C-*p*-hydroxybenzyl Isovitexin (Fig. 16), 8-C-*p*-hydroxybenzyl isovitexin 4'-*O*- β -D-glucoside (Fig. 17) (13). The methanolic extract (13.9%) of dried fruits of *C. colocynthis*, cultivated in Egypt, and contain Colocynthoside A (0.0036%, Fig. 18) and Colocynthoside B (0.018%, Fig. 19), were isolated together with Cucurbitacin E 2-*O*- β -D glucopyranoside (0.0077%, Fig. 10), 2-*O*- β -D glucopyranoside cucurbitacin I (0.15%, Fig. 9), colocynthoside (0.0015%, Fig. 20), 2-*O*- β -D glucopyranoside cucurbitacin J (0.0015%, Fig. 21), 2-*O*- β -D glucopyranoside cucurbitacin K (0.0007%, Fig. 22), 2-*O*- β -D glucopyranoside cucurbitacin L (0.032%, Fig. 23) (12, 34), hexanocucurbitacin I 2-*O*- β -D glucopyranoside (0.0020%, Fig. 24), khekadaengoside E (0.0014%, Fig. 25), isovitexin

(0.0039%, Fig. 7), isoorientin 3'-*O*-methyl ether (0.0032%, Fig. 8), isosaponarin (0.0005%, Fig. 26), 4-(β -D-glucopyranoside) benzaldehyde (0.0009%, Fig. 27), 4-hydroxybenzyl β -D-glucopyranoside (0.0009%, Fig. 28), benzyl- β -D-glucopyranoside (0.0006%, Fig. 29), 4-(β -D-glucopyranoside) benzyl alcohol (0.015%, Fig. 30) (35), these are isolated from n-butanol soluble fraction (36).

Cucurbitacins are a group of highly structurally diverse triterpenes, with a rich variety of side chain derivatives and different ring A substitution patterns. They have been mainly reported from plants of the *Cucurbitaceae*, but are also known from a few genera within other plant families, including the Brassicaceae. They are renowned for their bitter taste, but also possess a broad range of potent biological activities. Although the cytotoxicity of cucurbitacins was known before 1800 AD, very little is known about the mechanism of the effect of cucurbitacins at the cellular and molecular level, which

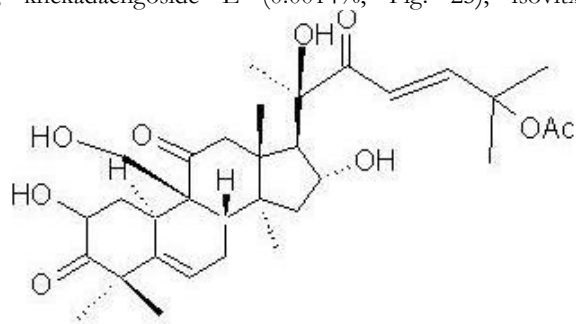


Figure 1: Cucurbitacin A

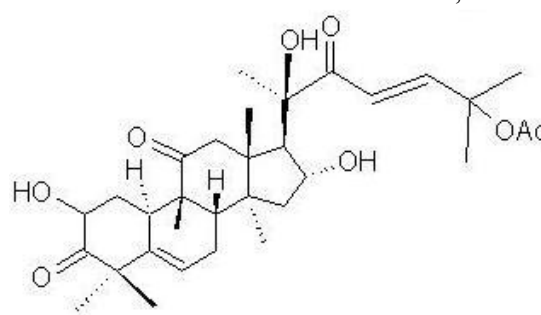


Figure 2: Cucurbitacin B

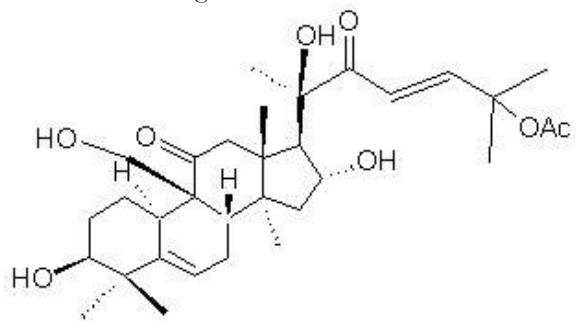


Figure 3: Cucurbitacin C

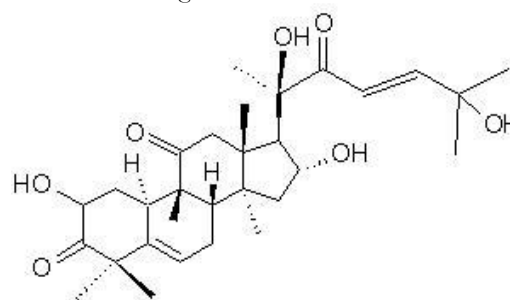


Figure 4: Cucurbitacin D

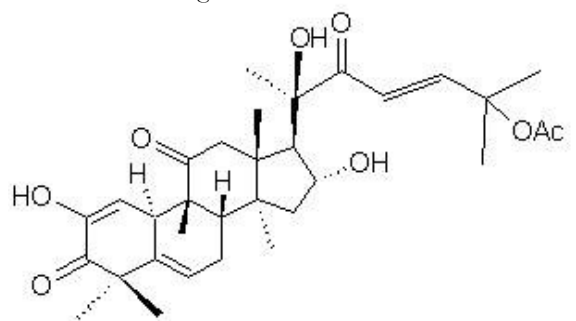


Figure 5: Cucurbitacin E (a-elaterin)

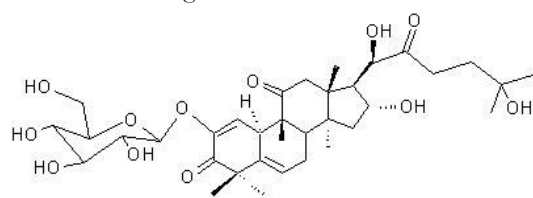
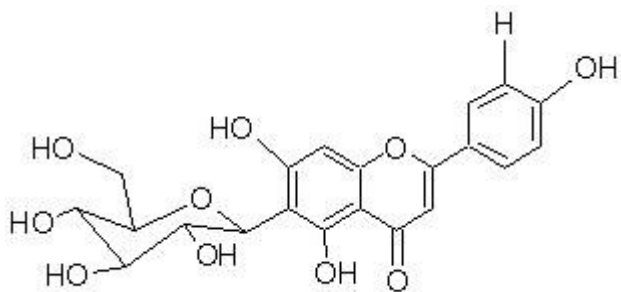
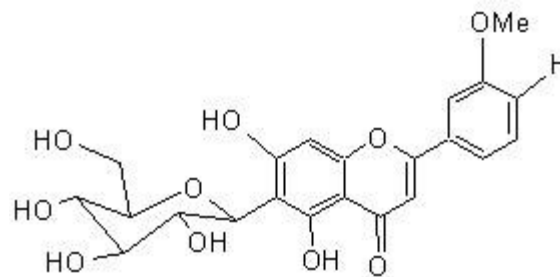


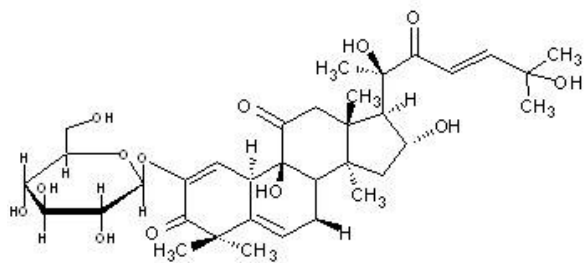
Figure 6: Isoscoparin



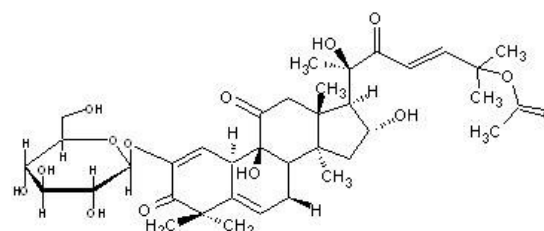
"Figure 7 Isovitexin"



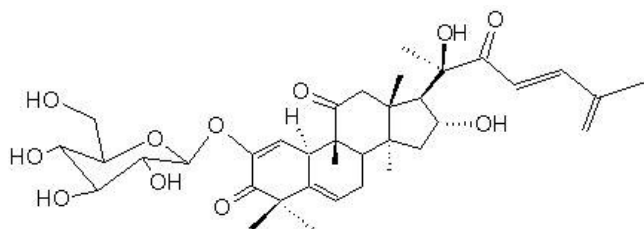
"Figure 8: Isoorientin 3'-O-methyl ether"



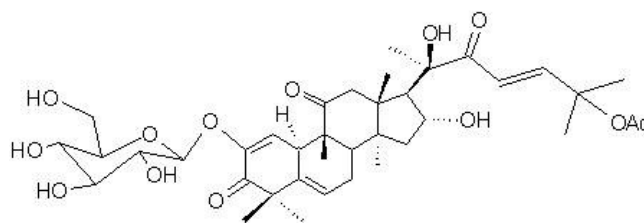
"Figure 9: Cucurbitacin I 2-O-β-D-glucopyranoside"



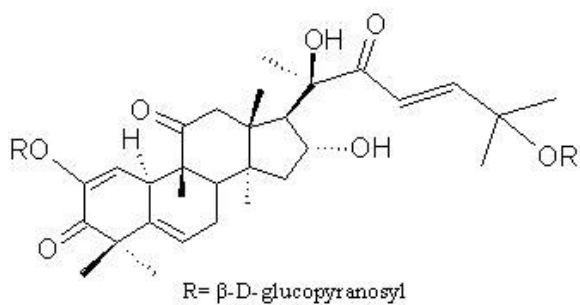
"Figure 10: Cucurbitacin E 2-O-β-D-glucopyranoside"



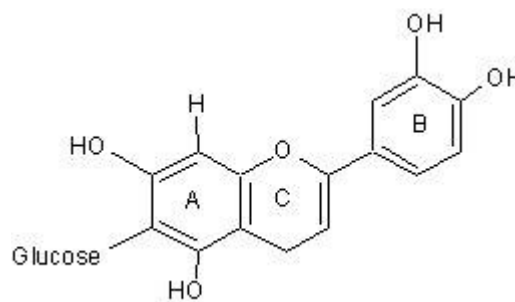
"Figure 11: New Compound"



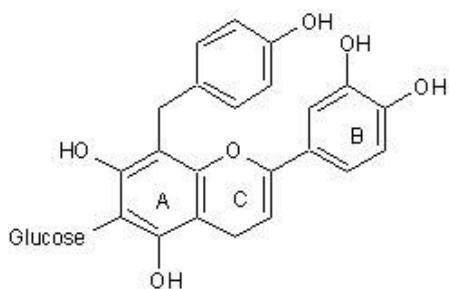
"Figure 12: 2-O-β-D glucopyranosyl cucurbitacin B (arvenin I)"



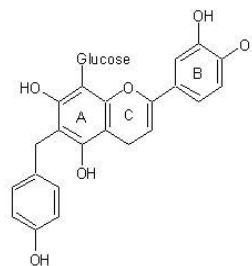
"Figure 13: 2, 25-di-O-β-D-glucopyranosyl-cucurbitacin L"



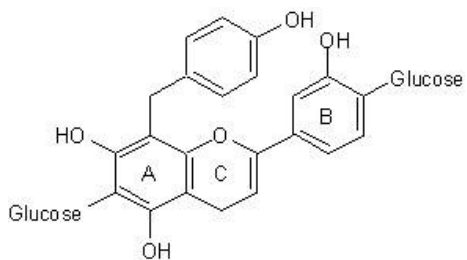
"Figure 14: Isoorientin"



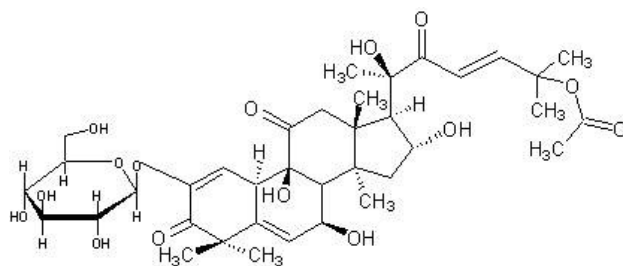
"Figure 15: Hydroxybenzyl Isovitexin"



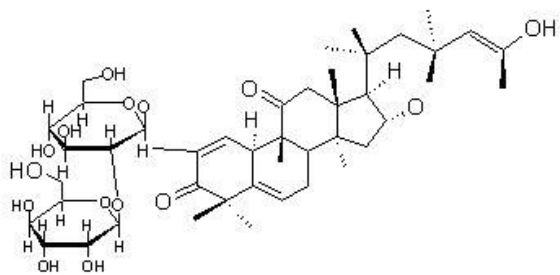
"Figure 16: 6-C-p-hydroxybenzyl Isovitexin"



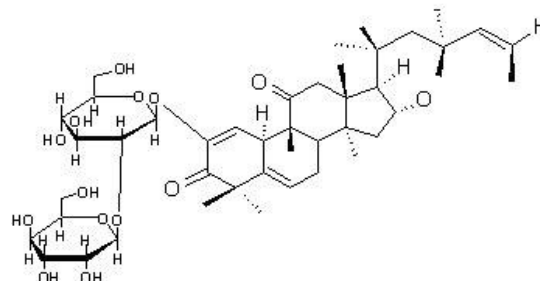
"Figure 17: 8-C-p-hydroxybenzyl isovitexin 4'-O-β-D-glucoside"



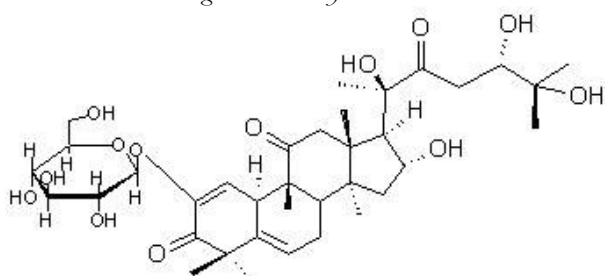
"Figure 18: Colocynthiside A"



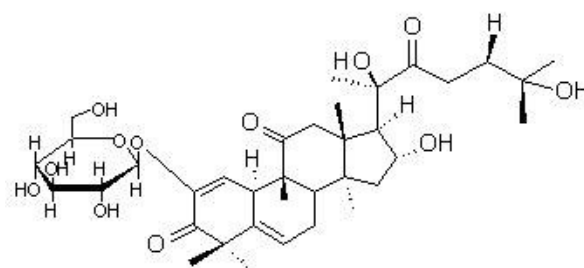
"Figure 19: Colocynthiside B"



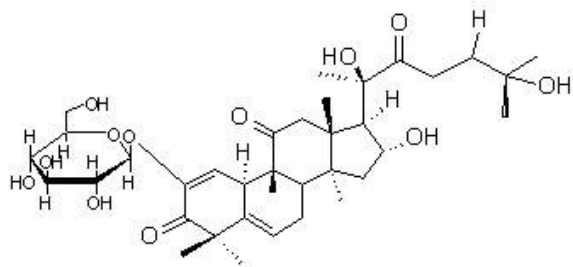
"Figure 20: Colocynthiside"



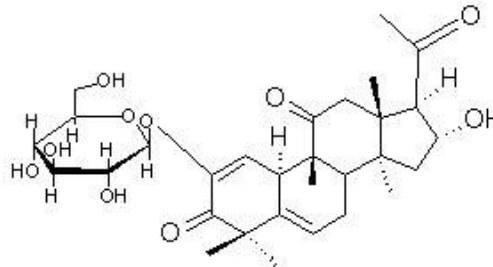
"Figure 21: Cucurbitacin J 2-O-β-D-glucopyranoside"



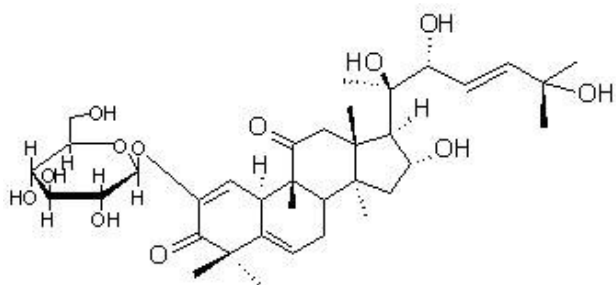
"Figure 22: Cucurbitacin K 2-O-β-D-glucopyranoside"



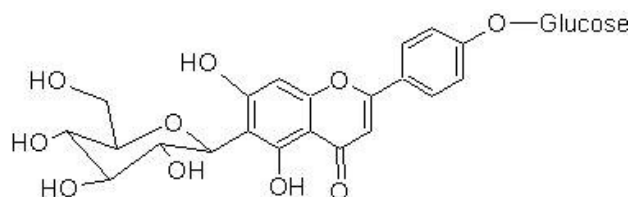
"Figure 23: Cucurbitacin L 2-O-β-D-glucopyranoside"



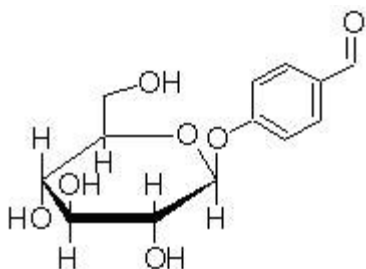
"Figure 24: Hexanocucurbitacin I 2-O-β-D-glucopyranoside"



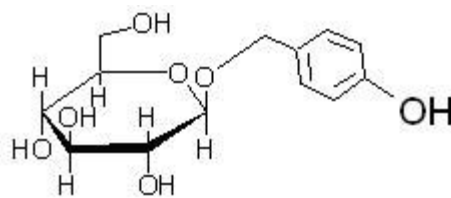
"Figure 25: Khekadaengoside E"



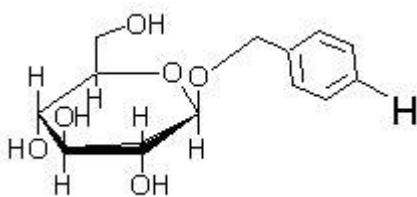
"Figure 26: Isosaponarin"



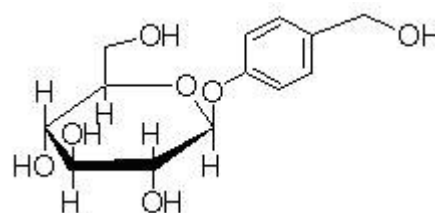
“Figure 27: 4-(β-D-glucopyranoside) benzaldehyde”



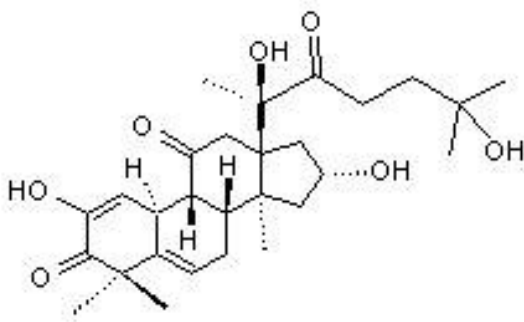
“Figure 28: 4-hydroxybenzyl β-D-glucopyranoside”



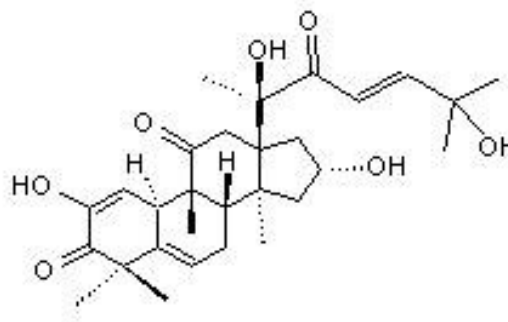
“Figure 29: Benzyl β-D-glucopyranoside”



“Figure 30: 4-(β-D-glucopyranoside) benzyl alcohol”



“Figure 31: Cucurbitacin L (23, 24-dihydrocucurbitacin I)”



“Figure 32: Cucurbitacin I”

accounts for the relatively slow advance in cucurbitacin based drug discovery.

BIOLOGICAL REVIEW

During biblical times, fruits of the colocynth or bitter apple or bitter ground were gathered as deadly poison. Fruits were widely used medicinally, especially for stomach pains. The pulp is an effective hydragogue, cathartic and laxative because of its content of glucosides such as colocynthis. The fruits, seeds and roots of *Citrullus Colocynthis* L. Schard plants are purgative and used as an antidote to snake poison. Root is also used for the treatment of jaundice, rheumatism and urinary diseases. It locally known as Handal or Sherry, commonly found in Saudi Arabia used as an antihelminthic, purgative, molluscicide and insecticide (37). The Cucurbitacin, a class of highly oxygenated, bitter tasting tri-terpene, have been shown to produce increased rat capillary permeability (38), to demonstrate anti-fertility effect in female mice (39), to possess anti-inflammatory activity (40-41), to exhibit phago-stimulant activity on corn rootworm (42) and to act as feeding deterrents (43) or as insect steroid hormone antagonist (44). The reported biological activities of the plant *Citrullus Colocynthis* includes:

Anti-inflammatory Activity

Colocynthis belongs to the mostly used plants in folk medicine because of the anti-inflammatory activity (45). The effect of chloroform and methanol extract of *Citrullus Colocynthis* on glucose homeostasis was studied in normal and diabetic rats. In addition, some pharmacological effects of an ethanolic leave extract (CCL) and the pulp (CCP) were also evaluated. Extract of seeds had no effect on fasting glucose levels or in the oral glucose tolerance test in normal or diabetic rats. Both CCL and CCP resulted in spastic contraction of the rabbit jejunum which were not blocked by atropine. No effect was observed in the rat uterus. CCL and CCP reduced the heart rate and force of contraction in isolated rabbit heart. At a dose 800mg/kg of ethanol extract, the leaves exhibited a secondary anti-inflammatory activity, but were severely toxic. At lower doses (100, 200 and 250 mg/kg), no anti-inflammatory activity was observed (46). *Citrullus* extract of *citrullus colocynthis* are known to stimulate intestinal peristalsis and to soften bowel contents by an irritant action on the enteric mucosa (47-48). Owing to the purgative effect of colocynth extract when taken orally, prepare a Sodium carboxymethyl cellulose (5%) topical gel formulations containing 3% of colocynth extract, hydrolyzed extract, or acetylated extract and to study their release through cellophane membrane and their permeability

through hairless mouse skin. Also, to study the *in vivo* anti-inflammatory activity of the different types of colocynth extract using the carrageenan induced paw edema model in albino rats in comparison with the commercial *Volartar Emulgel*[®]. The acetylated extract gel showed comparatively rapid permeability through hairless mouse skin, with low release rate through cellophane membrane. The pharmacological screening revealed that the percent reduction of edema produced by Colocynth extract was 45.39%, the hydrolyzed extract produced 54.11% inhibition and the acetylated extract produced 64.95%, while *Volartar Emulgel* produced 63.35%. This means that acetylated colocynth extract can be used as an effective local anti-inflammatory agent (49).

Anti-Diabetic Activity

Different extracts were obtained from seeds, the major free acids derivative present in the seeds. This study showed the insulinotropic effect of *Citrullus colocynthis* fruits. Different extracts were obtained from the seeds of this plant: RN II (crude extract), RN VI (aqueous alcoholic extract), RN X (purified extract) and RN XVII (beta-pyrazol-1-ylalanine, the major free amino acid derivative present in the seeds). All tested extracts, when perfused for 20 min at 0.1 mg/ml, immediately and significantly induced insulin secretion *in-vitro* in the isolated rat pancreas and isolated rat islets in the presence of 8.3 mM glucose. In normoglycaemic rabbits, oral administration of the aqueous extract (300 mg/kg) caused a significant reduction in glycaemia after 1 h and a highly significant reduction after 2, 3, and 6 h. Oral administration of components isolated from the rind of *C. colocynthis* (tertiary and quaternary alkaloids, glycosides and saponins) were tested in normoglycaemic rabbits at a dose of 50 mg/kg. The alkaloids did not show any hypoglycaemic effect. In contrast, the glycosidic component significantly decreased glycaemia after 2 and 3 h and even more significantly after 6 h. The saponin component reduced glycaemia after 1, 2, 3 and 6h. Oral administration of graded doses of saponin extract (10, 15 and 20 mg/kg) caused a marked hypoglycaemic effect in alloxan-induced diabetic rabbits. The saponin glycosides components could be responsible for the hypoglycaemic effect of the rind of *C. colocynthis* (50). The effect of the aqueous, glycosidic, alkaloidal and saponin extract of the rind *Citrullus colocynthis* on the plasma glucose level in normal rabbits while the effect of saponin extract on the fasting plasma glucose levels were studied in alloxan induced diabetic rabbits. In normal rabbits, oral administration of aqueous extract (500 mg/kg) produced significant reduction in plasma glucose after 1hrs and highly significant after 2, 3 and 6 hrs (51).

Citrullus colocynthis (L.) Schrad fruit is an herbal medicine used by traditional herbalists for the treatment of diabetes in Iran. To determine its efficacy and toxicity, a 2 month clinical trial was conducted in 50 type II diabetic patients. Two groups of 25 each under standard anti-diabetic therapy, received 100mg *C. colocynthis* fruit capsules or placebos three times a day, respectively. The patients were visited monthly and glycosylated hemoglobin (HbA1c), fasting blood glucose, total cholesterol, low density lipoprotein (LDL), high density

lipoprotein (HDL), triglyceride, aspartate transaminase, alanine transaminase, alkaline phosphatase, urea and creatinine levels were determined at the beginning and after 2 months. The results showed a significant decrease in HbA1c and fasting blood glucose levels in *C. colocynthis* treated patients. Other serological parameters levels in both the groups did not change significantly. No notable gastrointestinal side effect was observed in either group. In conclusion, *C. colocynthis* fruit treatment had a beneficial effect on improving the glycemic profile without severe adverse effects in type II diabetic patients. Further clinical studies are recommended to evaluate the long-term efficacy and toxicity of *C. colocynthis* in diabetic patients (52).

In UAE many traditional plants such as the *Citrullus colocynthis* (Handal) are used as antidiabetic remedies. The effect of the aqueous extracts of the seed of *C. colocynthis* the biochemical parameters of normal and streptozotocin (STZ)-induced diabetic rats. Diabetes mellitus was induced by a single intraperitoneal (60 mg/kg body wt1) injection of STZ. Normal and diabetic rats were fed with the plant extract daily by oral intubation for 2 weeks. Blood sample were collected at the beginning and end of the experiment for the measurement of biochemical parameters. The plasma level of alanine aminotranferase (ALT), alkaline phosphatase (ALP), aspartate aminotransferase (AST), gamma-glutamyl transferase (GGT), lactic dehydrogenase (LDH) increased significantly after the onset of diabetes. Oral administration of the plant extract reduced the plasma level of AST and LDH significantly. However, the plant extract failed to reduce the increased blood level of GGT and ALP in diabetic rats. Blood urea nitrogen (BUN) increased significantly after the onset of diabetes. No significant difference was observed in the blood creatinine, K⁺, Na⁺, Ca²⁺ and P levels of normal and diabetic rats. The plant extract did not have any effect on BUN level; however, it caused an increase in the level of K⁺, Na⁺ in diabetic rats. In conclusion, oral administration of the aqueous extract of the *C. colocynthis* can ameliorate some of the toxic effects of streptozotocin (53).

Citrullus colocynthis (colocynth) seeds are traditionally used as anti-diabetic medication in Mediterranean countries. The present study evaluated the differential effects of diets enriched with *C. colocynthis*, sunflower or olive oils on the pancreatic β -cell mass in streptozotocin (STZ)-induced diabetes in rats. STZ injection induced rapid hyperglycaemia in all animals. However, 2 months later, hyperglycaemia was significantly less pronounced in the rats fed a *C. Colocynthis* oil-enriched diet compared with other rat groups (7.9 mM *vs* 12 mM and 16 mM with colocynth versus olive and sunflower oils, respectively). Assessment of insulin sensitivity using the homoeostasis model assessment (HOMA) method also indicated less insulin resistance in the rats fed a *C. colocynthis* oil-enriched diet *vs* the other rats. Finally, 2 months after STZ injection, the pancreatic β -cell mass was similar in both the STZ-treated rats fed the colocynth oil-enriched diet and their controls fed the same diet? In contrast, the pancreatic β -cell mass remained lower in the STZ-induced diabetic rats fed with olive oil- and sunflower oil-enriched diets compared with

the *C. colocynthis* group. *C. colocynthis* oil supplementation may have a beneficial effect by partly preserving or restoring pancreatic β -cell mass in the STZ-induced diabetes rat model (54).

Anticancer activity

The effect of cucurbitacin glucosides extracted from *Citrullus colocynthis* leaves on human breast cancer cell growth, cell-cycle distribution, apoptosis and expression of protein involved in cell-cycle regulation, utilizing both estrogen-dependent (MCF-7) and estrogen-independent (MDA-MB-231) human breast cancer cell lines. Leaves were extracted, resulting in the identification of cucurbitacin B/E glucosides. The cucurbitacin glucosides combination (1:1) inhibited growth of ER⁺ MCF-7 and ER⁻ MDA-MB-231 human breast cancer cell lines. Cell-cycle analysis showed that treatment with isolated cucurbitacin glucoside combination resulted in accumulation of cells at the G₂/M phase of the cell cycle. Treated cells showed rapid reduction in the level of the key protein complex necessary to the regulation of G₂ exit and initiation of mitosis, namely the p34^{CD₂}/cyclin B1 complex. Cucurbitacin glucoside treatment also caused changes in the overall cell morphology from an elongated form to a round-shaped cell, which indicates that cucurbitacin treatment caused impairment of actin filament organization. This profound morphological change might also influence intracellular signaling by molecules such as PKB, resulting in inhibition in the transmission of survival signals. Reduction in PKB phosphorylation and inhibition of survivin, an anti-apoptosis family member, was observed (55).

Hep-2 (a human laryngeal cancer cell line) cells were treated with different concentrations of cucurbitacin B for different time. MTT (3-(4, 5-dimethylthiazol-2-yl)-2, 5-diphenyl tetrazolium bromide) assay was used to evaluate cell proliferation. Flow cytometry with PI staining and fluorescent microscopy with Hoechst 33258 staining were used to estimate cell cycle distribution and cell apoptosis. Expression of p-STAT3 (signal transducers and activators of transcription 3), cyclin B1 and Bcl-2 proteins was evaluated by Western blot assay. *In-vivo* inhibitory effects of cucurbitacin B on tumor growth was evaluated in a nude mouse xeno-graft model. Cucurbitacin B inhibited cellular proliferation in a dose and time dependent manner (P <0.05 or 0.01). Flow cytometry analysis showed that treatment with cucurbitacin B resulted in accumulation of cells at the G₂/M phase of the cell cycle and cell apoptosis in a dose and time dependent manner (P <0.05 or P <0.01). Marked morphological changes of cell apoptosis including condensation of chromatin, nuclear fragmentation and apoptotic bodies were observed clearly by Hoechst 33258 staining. Western blot analysis demonstrated that the expression of p-STAT3, cyclin B1 and Bcl-2 proteins was suppressed significantly. *In-vivo* studies showed that the inhibitory rates on laryngeal squamous carcinoma xenograft model were 32.43%, 43.24% and 70.27% for lower, moderate and higher dosage group, respectively. Cucurbitacin B inhibited cell proliferation and induced apoptosis of Hep-2 cells by suppressing STAT3 signal pathway, down regulating the expression of cyclin B1 and Bcl-2 proteins (56).

The combined antitumor effect of cucurbitacin B with docetaxel on Hep-2 (a human laryngeal cancer cell line); treated Hep-2 cells with cucurbitacin B alone or in combination with docetaxel and evaluated cell growth, cell cycle distribution, and apoptosis using MTT (3-(4, 5-dimethylthiazol-2-yl)-2, 5-diphenyl tetrazolium bromide) assay, flow cytometry, and fluorescent microscopy. Our results showed that, in comparison with single agent treatment, the combination of cucurbitacin B and docetaxel produced greater efficacy in growth inhibition, cell cycle arrest at G₂/M phase, and apoptosis induction. Measuring the modulation of regulators in the cell cycle, apoptosis and signal transductions by Western blot analysis showed that the combination effect of cucurbitacin B and docetaxel was due to suppress the expression of p-STAT3 (signal transducers and activators of transcription 3), Bcl-2, and cyclin B1. Moreover, our *in vivo* studies were reproduced in a mouse xenograft model, where, the combination of cucurbitacin B with docetaxel synergistically inhibited tumor growth. Together, this investigation suggests that cucurbitacin B combined with docetaxel may be a feasible strategy to enhance the effects of chemotherapy in patients with laryngeal cancer (57).

Glioblastoma Multiforme (GBM) is almost inevitably a fatal tumor of the brain with most individuals dying within 1 year of diagnosis. It is the most frequent brain tumor in adults. Dose-response studies showed that Cucurbitacin B inhibited 50% growth (ED₅₀) of 5 human GBM cell lines in liquid culture at $\sim 10^{-7}$ M. Soft-gel assays demonstrated that nearly all of the GBM clonogenic cells were inhibited at 10⁻⁸ M of Cucurbitacin B. FACS analysis found that the compound (10⁻⁷ M, 24 hr) caused G₂/M arrest. The GBM cells underwent profound morphologic changes within 15-30 min after exposure to Cucurbitacin B (10⁻⁷ M), rounding up and losing their pseudopodia associated with disruption of actin and microtubules, as observed by immuno-flourescence. Cucurbitacin B (10⁻⁷ M) caused prominent multinucleation of the cells after they were pulse-exposed (48 hr) to the drug, washed and cultured in normal medium for an additional 2 days. The drug (10⁻⁷ M, 3-24 hr) increased levels of p-p38, p-JNK and p-JUN in U87 and T98G GBM cell lines as seen by Western blot. Interestingly, alterations in cell morphology caused by Cucurbitacin B (10⁻⁷ M) were blocked by the JNK inhibitor SP600125. Cucurbitacin B has a prominent anti-proliferative activity on GBM cells; and at least in part, the mode of action is by affecting the cytoskeleton, as well as, the JNK pathway. Clinical trails of this drug should be pursued in GBM. © 2008 Wiley-Liss, Inc (58). Cucurbitacin E has also received great attention because of their cytotoxic and anticancer effects. Cucurbitacin L (23, 24-dihydrocucurbitacin I, Fig. 31) was also cytotoxic against KB and HeLa cell lines, but was less potent than cucurbitacin I (Fig. 32), which was isolated from *Citrullus colocynthis* (59-60, 24).

Anti-spermatogenic Activity

The antispermatogenic effect of an ethanolic extract of *Citrullus colocynthis* root was studied by Mali et al. in male albino rats. A crude 50% ethanol extract of *Citrullus colocynthis* roots was administered orally to male albino rats at dose levels of 50,

100, and 200 mg/kg for a period of 60 days for evaluation of antifertility effects. Significant decreases in cauda epididymal sperm motility, density, number of pups and fertility were observed in all treatment groups. A marked reduction in the weight of testes, epididymis and seminal vesicle was observed. The weight of the ventral prostate was non-significantly decreased. The ethanolic extract of the fruits produced stimulation, accompanied by increased motor activity, tremors, convulsions, diarrhoea and rapid irregular respiration preceding death in mice. The spermatogenic disfunction was also significant. The same extract demonstrated cytotoxic as well as mutagenic effects. It causes irritation of stomach and intestine. It is seldom prescribed alone. It induced haemorrhagic colitis. Three examples of toxic acute colitis were reported after ingestion of colocynth for ritual purposes. Its clinical feature was dysenteric diarrhoea (61).

Chaturevedi et al. have study the induction of reversible antifertility with a crude ethanol extract of for *Citrullus colocynthis* fruits in male rats. A crude 50% ethanol extract of for *Citrullus colocynthis* was administered orally to male albino rats for evaluation of anti-fertility effects. The animal were divided in to five group; group A was vehicle treated control group; treatment group B, C, D and E received 100 mg/kg/day for *Citrullus colocynthis* extract for periods of 20, 40, 60 days respectively. A 50% ethanol extracts of for *Citrullus colocynthis* showed an antiandrogenic nature, thereby reduced reversible infertility in male albino rats (62). The effect of *Citrullus colocynthis* on reproductive system and fertility in female Spague-Dawely rats, the results indicate that long term exposure of *Citrullus colocynthis* causes adverse effect on reproductive system (63).

Citrullus colocynthis is used in traditional medicine to inhibit the implantation of embryos. This study was to determine the number of embryos per pregnancy and the mortality rate in pregnant mice. 115 vaginal plug-positive mice were divided into 4 groups. The animals were given 30, 60 and 120 mg/kg hydroalcoholic extract of *Citrullus colocynthis* until 17th day of gestation. Control group was fed with solvent. At the day 17, the animals were sacrificed and the number of pregnant mice and embryos per pregnancy were counted. We found that while in 30 mg/kg group the mean number of embryos per pregnancy was around 10, no embryo was found in other groups. Furthermore, 3 out of 30 mice in 30 mg/kg group died, while in 60 mg/kg and 120 mg/kg groups the number of death was 7 and 14, respectively. A significant increase in the mortality rate was observed in groups treated with higher doses (60 and 120 mg/kg) of *C. colocynthis* in a dose-dependent manner ($P < 0.05$). The fertility rate was significantly reduced as the dose increased ($P < 0.05$), so that with higher doses, there were no pregnant mice. The total number of pregnant mice was significantly reduced in comparison to the control group, by exposure to the extract with concentrations of 60 and 120 mg/kg, although the mean number of fetuses per pregnancy was constant. According to the data, LD₅₀ of *C. colocynthis* was calculated to be 100 mg/kg. This dose is close to those which induce maximal infertility effects. As the results of the present study showed, hydro-alcoholic extract of *C. colocynthis* causes a

decrease in fertility rate in a dose dependent manner but it has not any effects on the number of fetuses (64).

Antibacterial and Antioxidant Activity

The antibacterial screening for *Citrullus colocynthis*, the crude ethanolic extract of fruits, leaves, stems and root were examined for the potentialities against gram positive and gram negative bacilli. by Memon et al. Ethanolic extract of these parts to be active against gram positive bacilli, viz., *Bacillus pumilus* and *Staphylococcus aureus*, while fruit and root double strength gave positive result against ggram positive bacillus (*Bacillus subtilis*). The negative bacillus *E. coli* and *Pseudomonas aeruginosa* showed no response (65).

The larvicidal activity of crude acetone, hexane, ethyl acetate, methanol, and petroleum ether extracts of whole plant of *Citrullus colocynthis* (L.) Schrad and were assayed for their toxicity against the early fourth instar larvae of *Culex quinquefasciatus* (Diptera: Culicidae). The extract was concentrated under reduced pressure 22–26 mm Hg at 45°C and the residue obtained was stored at 4°C. The larval mortality was observed after 24 h exposure. All extracts showed moderate larvicidal effects; however, the highest larval mortality was found in whole plant petroleum ether extract of *C. colocynthis*. In this study, bioassay-guided fractionation of petroleum ether extract led to the separation and identification of fatty acids; oleic acid and linoleic acid were isolated and identified as mosquito larvicidal compounds. Oleic and Linoleic acids were quite potent against fourth instar larvae of *Aedes aegypti* L. (LC₅₀ 8.80, 18.20 and LC₉₀ 35.39, 96.33 ppm), *Anopheles stephensi* Liston (LC₅₀ 9.79, 11.49 and LC₉₀ 37.42, 47.35 ppm), and *Culex quinquefasciatus* say (LC₅₀ 7.66, 27.24 and LC₉₀ 30.71, 70.38 ppm). The results of this study clearly show that the extract and fraction of *C. colocynthis* that contain oleic and linoleic acid demonstrate a high larval mortality. However it is the first report of isolated active fraction tested for mosquito larvicidal activity. Thus, isolated compounds of the petroleum ether extract of *C. colocynthis* have potential to be developed as natural larvicidal agent (66).

Preliminary phytochemical screening of the plant showed the presence of large amounts of phenolics and flavonoids. Subsequent quantification showed the presence of 0.74% (*m/m*) phenolics (calculated as gallic acid) and 0.13% (*m/m*) flavonoids calculated as catechin equivalents per 100 g of fresh mass. The presence of phenolic compounds prompted us to evaluate its antioxidant activity. In the methanolic fruit extract of *C. colocynthis* was screened to evaluate its free-radical scavenging effect. Free radical scavenging effect of *Citrullus colocynthis* fruit increases with increasing concentration and maximum antioxidant activity was observed 2.5 g/ml (67).

Three flavone glucosides; isosaponarin (Fig. 6), isovitexin (Fig. 7) and isoorientin 3^o-O-methyl ether (Fig. 8) showed significant antioxidant properties. The antioxidant property of the three flavonoids was determined by the 2, 2-diphenyl-1-picrylhydrazyl (DPPH) assay. A solution of DPPH (0.08 mg/mL) in MeOH was used. The compounds were dissolved in methanol to obtain a concentration of 1×10^{-1} mg/mL. Dilutions were made to obtained concentrations of 5.00×10^{-2} , 2.5×10^{-2} , 1.25×10^{-2} , 6.25×10^{-3} , 3.13×10^{-3} , 1.56×10^{-3} mg/mL.

Diluted solutions (5 mL each) were mixed with DPPH (5 mL) and allowed half hour for any reaction to occur. The UV absorbance was recorded at 517 nm. The experiment was performed in duplicate and average absorption was noted for each concentration. Data were processed using EXCEL and the concentration that caused a 50% reduction in absorbance (RC_{50}) was calculated. The same procedure was followed for the standard (quercetin). The antioxidant activity of three flavonoids was determined by this method and the RC_{50} values were found to be 7.13×10^{-2} , 5.62×10^{-4} and 3.47×10^{-3} mg/mL, respectively. The RC_{50} value of the positive control, quercetin, was 2.78×10^{-5} mg/mL. Since reactive oxygen species are important contributors to tissue injury, inflammation, cancer and many other ailments, the antioxidant properties of three flavonoids probably contribute, at least to some extent, to the pharmacological and traditional medicinal uses of the *C. colocynthis*. (25)

The antioxidant properties of cucurbitacin B + E glucosides (cucurbitacin glucoside combination, CGC) and their direct free-radical scavenging properties, using ESR spectroscopy; Antioxidant activity was measured by the ability of the CGC to reduce preformed ABTS^{•+} into its native form and to inhibit MDA formation during the oxidation of linoleic acid. In both methods, the CGC exhibited antioxidant activity in a dose-dependent manner as expected from antioxidants. Using ESR spectroscopy, we found that the CGC inhibited [•]OH-dependent DEPMPO–OH adduct formation, O₂^{•-}-dependent DEPMPO–OOH adduct formation, and the ¹O₂-dependent TEMPO adduct generated in the photoradiation–porphyrin system. The IC₅₀ values were 0.38, 8, and 11 mM, respectively. Together, these data demonstrate that the CGC exhibits antioxidant properties, probably through the involvement of a direct scavenging effect on several free radicals (68).

Miscellaneous activity

The hypolipidaemic effect of *Citrullus colocynthis* in rabbits; the plant extract was orally administered to the atherogenic rabbits (atherogenic + cholesterol + powder supplement 400 mg/kg/body weight/day dissolved in 5ml coconut oil) at dose of 1.2 g/kg body weight/day. During the period of the experiment blood was collected and serum was analyzed for lipid profile. Animals were sacrificed; the heart and liver were collected and kept -20°C until assayed. Biochemical analysis of blood serum and tissue (liver and heart muscle) level were made for cholesterol, phospholipids and triglycerides. In addition blood serum was analyzed further for high density lipoprotein (HDL)-Cholesterol and all results were statistically analyzed using t-test. Hypolipidaemic nature of *Citrullus Colocynthis* (70% ethanol) extract was studied in hyperlipidaemic rabbits. The increased cholesterol levels were brought to normal by administration of *C. colocynthis*. Serum cholesterol levels were dropped from 940.7 to 230.41 (75.55%) and further to 119.2 (87.32%) by end of the experiment. Similarly, phospholipids and triglycerides levels were observed to be also reduced. *C. colocynthis* possess active hypolipidaemic constituents (69).

The anti-allergic constituent on the methanolic fruit extract of *Citrullus colocynthis* showed an inhibitory effect on ear passive

cutaneous anaphylaxis as a type I allergic model in mice. The Cucurbitacin E 2-O-β-D-glucopyranoside and its aglycon exhibited anti-allergic activity at a dose of 100 and 1.25 mg/kg, p.o., respectively (36). The hepato-protective activity of *Citrullus colocynthis* extract against carbon tetrachloride induced hepatic damage in albino rats. Ethanolic and aqueous extract of root were used and albino rats were challenged with carbon tetrachloride (2.5 mg/kg in groundnut oil, p.o.). *Citrullus colocynthis* root and fruit extract showed significant hepato-protective action in carbon tetrachloride challenged rats (70). The effect of saponin (extracted from plant *Citrullus colocynthis*) on mortality and histopathology change in mice, Diman et al. (71) evaluated the acute toxicity and histopathological effect of saponin on mice in order to assess its safety. The median lethal dose (LD₅₀) of the saponin was 200mg/kg.

The heat-induced gelation of whole equi (*Citrullus colocynthis* L.) seeds were studied by Uruakpa et al. Despite the use of whole equi seeds as a food ingredient for generation, there is no report on its gelling ability (72). The immuno-stimulating activity of hot water soluble polysaccharides extracts of *Anacyclus pyrethrum*, *Alpinia galangal* and *Citrullus colocynthis*. The results of the *in-vivo* effect at dose 50 and 25 mg/kg for *Anacyclus pyrethrum* and *Alpinia galangal*. While extract of *Citrullus colocynthis* showed much weaker and variable immuno-stimulating activity (73). The development and evaluation of polyherbal formulation for hair growth-promoting activity; it was envisaged to preparation containing petroleum ether extract of the three herbs (*Cuscuta reflexa*, *Citrullus colocynthis* Schard. and *Eclipta alba*) in varying ratio and evaluating the formulation promoting activity (74).

A standardized extract of *Citrullus colocynthis* used as oral natural laxative in folk medicine was tested for its influence on liver function parameters *in-vitro*. Cytochrome P450 (CYP) dependent production of reactive oxygen species (ROS) under the influence of *Citrullus colocynthis* extract was investigated by means of stimulated lipid peroxidation (LPO), H₂O₂ formation and amplified chemiluminescence in rat liver microsomes. In rat liver 9000 × g supernatants 4 monooxygenase reactions mediated by different CYP forms were measured. Putative hepatotoxic effects of *Citrullus colocynthis* extract were measured by means of potassium and GSH concentrations in and LDH leakage from precision-cut rat liver slices. For possible hepatoprotective effects the influence of the extract on carbon tetrachloride-induced changes of these parameters was investigated. *Citrullus colocynthis* extract in concentrations higher than 10 µg/ml incubation mixture proved to inhibit lipid peroxidation and ROS-production as well as CYP1A-, 2B- and 3A-dependent reactions with typical substrates. In contrast, H₂O₂ production was not reduced under the influence of the extract, a slight but significant increase was seen. *Citrullus colocynthis* extract was found to be free of hepatotoxic effect in concentration up to 100 µg/ml incubation mixture when liver slices were incubated in *William medium E* for 22 hrs (75).

The dried pulp of its fruits was used as a traditional medicine mostly for constipation (76). In Saudi Arabia, the Arabs that even treading barefoot on the squeezed fruit is enough to elicit

its purgative action but in East Africa, the seed tar was used by nomads in traditional medication applied to the skin (77). The ingestion of the cathartics fruit can have many undesired effects including bloody diarrhoea (76) and even true acute toxic colitis and change in the colon similar to these other laxative abuse (47-48).

TOXICITY

Citrullus colocynthis seed was fed at 2% and 10% of the basal diet to 7-d-old Bovans-type chicks for 6 w. Average body weights and efficiency of feed utilization were markedly depressed in the chicks on 10% *Citrullus* feed, and the serum activities of LDH, AST and CK and concentrations of total lipid and zinc were significantly increased. The concentration of serum total iron binding capacity was particularly reduced in chicks on 2% *Citrullus* feed. The concentrations of other serum and blood constituents and of hepatic copper, manganese and zinc were not significantly changes. Lesions seen in the intestines, livers, kidneys and other tissues were fully reversed 4 weeks after removal from the experimental diet (78).

Citrullus colocynthis, which is used by diabetic patients as a hypoglycemic agent, but it, has been reported to cause gastrointestinal disorders after consumption in some patients. 50 rats were randomly divided into five groups (4 experimental and 1 controls). In the experimental groups a single daily dose of alcoholic extract of *Citrullus colocynthis* (50, 100, 200, 400 g/kg) was administered intraperitoneally. Normal saline was administered in control group. After two weeks, the rats were killed and the livers were removed and fixed with formalin (10%). Specimens were then processed and stained with H&E and Reticuline. The results indicated that there is a morphological change in liver cells including karyorrhexis, chromatolysis, and granulation of the cytoplasm. Additionally, collagen and reticular fibers were evident in liver parenchyma in high doses. *Citrullus colocynthis* can have toxic effects on liver cells which may induce hepatocyte necrosis and liver fibrosis. These effects were dose dependent (79).

The preliminary toxicity on the individual and combined effect of *Citrullus Colocynthis* and *Nerium oleander* in rat, the toxicity of diet containing 10% *Citrullus Colocynthis* fruits or 10% *Nerium oleander* leaves or their 1:1 mixture. The rat treated for 6 weeks. Resulting dullness, ruffled hair, decreased body weight gains and feed efficiency and enterohepatonephropathy characterized by treatment with *Citrullus Colocynthis* and *Nerium oleander* given alone. Diarrhoea was a prominent sign of *Citrullus Colocynthis* poisoning. The combination effects of *Capsicum frutescens* and *Citrullus colocynthis* on growth, haematological and pathophysiological parameters of rats. The toxicity diet contain 10% *Capsicum frutescens* and 10% *Citrullus colocynthis* fruit or their 1:1 ratio mixture to rats treated for 6 weeks was evaluated. Body weight loss, inefficiency of feed utilization, diarrhoea and enterohepatonephropathy characterized *Citrullus colocynthis* toxicosis in rats (80-81).

Sheep which were fed fresh *Citrullus colocynthis* fruits and leaves (0.2-10 g/kg) showed signs of poisoning (82). Doses of 10 g/kg of *Citrullus colocynthis* from 1 day to 2 weeks caused death in goats (83). The other side-effects of this plant are toxic

acute colitis (47), reversible infertility (62) and hepato-toxicity in rats (75). These damages were sometimes enhanced with higher doses of *Citrullus colocynthis*.

CONCLUSION

Plants have potent biochemicals and have components of phytomedicine. Since time immemorial; man is able to obtain from them a splendid assortment of industrial chemicals. The medicinal actions of plants are unique to particular plant species or groups and are consistent with this concept as the combination of secondary products in a particular plant is taxonomically distinct. With more structurally diverse cucurbitacin-related compounds being isolated and characterized from natural sources, coupled with the advance of molecular pharmacology of cancer and inflammatory diseases, which allows activities to be assayed rapidly and molecular mechanisms deciphered, it can be anticipated that some lead compounds will be identified which could be used as templates for drug discovery.

REFERENCES

1. The Ayurvedic Pharmacopoeia of India (1st Ed.) Part-I, Vol.-II (1991).
2. K.R. Kirtikar and B.D. Basu. *Indian Medicinal Plants*, Vol. II, International Book Distributors, DehraDun (1988).
3. A.C. Dey. *Indian Medicinal Plants Used in Ayurvedic Preparations*, (Bishen Singh, Mahendra Pal Singh, Dehra Dun, 1980) 202.
4. V.V. Sivarajan and I. Balachandran. *Ayurvedic Drugs and their Plant Sources*. Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi. (1994) 570.
5. K.M. Nadkarni, *Indian Medicinal Plants and Drugs- with their Medicinal Properties and Uses*, (Asiatic Publishing House, New Delhi, 1998) 450.
6. A. Husain, O.P. Virmani, S.P. Popli, L.N. Misra, M.M. Gupta, G.N. Srivastava, Z. Abraham and A.K. Singh. *Dictionary of Indian Medicinal Plants*. CIMAP, Lucknow, India, 546 (1992).
7. A.K. Nadkarni. *Dr. K.M. Nadkarni's Indian Materia Medica*. Vol I, Sangam Books, London, 1982.
8. D. Zohary and M. Hopf. *Domestication of plants in the old world*, Oxford university press, Oxford, UK, 2000.
9. A. Yokota, S. Kawasaki, M. Iwano, C. Nakamura, C. Miyake and K. Akashi. Citrulline and DRIP-1 Protein (Arg E Homologue) in drought tolerance of wild watermelon. *Ann Bot*. **89**: 825-832 (2002).
10. G.E. Trease and W.C. Evans, *Pharmacognosy*, (Billiere & Tindall, London, 1983), 250.
11. L.K. Yankov and S.M. Hussein. Fatty acid from the oil of the seeds of *Citrullus colocynthis*. *Dokl Bolg Akad Nauk*. **28**: 209-212 (1975).
12. N.A.R. Hatam, A.W. Donald and N.J. Yousif. Cucurbitacin glycosides from *Citrullus colocynthis*. *Phytochemistry*. **59**: 1268-1271 (1989).
13. G.T. Maatooq, S.H. El-Sharkawy, M.S. Afifi and J.P.N. Rosazza. C-p-hydroxybenzoyl glycoflavones from *Citrullus colocynthis*. *Phytochemistry*. **44**: 187-190 (1997).
14. R. Nmila, R. Gross, H. Rchid, M. Roje, M. Manteghetti, P. Petit, M. Tijane, G. Ribes and Y. Sauvaire. Insulinotropic effect of *Citrullus colocynthis* fruit extracts. *Plant Medica*. **66**: 418-423 (2000).
15. G.V. Satyawati, M.K. Raina, E.P. Ellmerer and H. Stuppner. ¹H and ¹³C-NMR signal assignment of cucurbitacin derivatives from *Citrullus Colocynthis* L. *Scharder and Ecballium Elaterium* L. (Cucurbitaceae). *Mag Reson Chem*. **43**: 489-491 (2005).
16. Dr. Duke's, Phytochemical and Ethnobotanical Databases, Chemical in *Citrullus colocynthis* (Cucurbitaceae), Available on-line at: <http://www.ars-grin.gov/cgi-bin/duke/farmac2.pl>, 2006.
17. O. Oyulu. A qualitative and quantitative study of seed types in 'egusi' (*Colocynthis citrullus* L.). *Trop Sci*. **19**: 51-61 (1977)
18. A.M. Abaleu, M.A. Makinde and E.O. Akinrimisi. Melon (egusi) seed protein 1: study of amino acid composition of defatted meal. *Nutr Rep Int*. **20**: 605-613 (1979).
19. V.A. Oyenuga. *Nigeria's food and feedstuffs: Their Chemistry and nutritive value*. 3rd Ed., Ibadan University Press, Ibadan, 1968.
20. S.A. Odunfa. Microbiology and amino acid composition of 'ogiri'- a food condiment from melon seeds. *Nahrung*. **25**: 811-816 (1981).

21. P. Girgis and F. Said. Lesser known Nigerian edible oils and fats 1: Characteristic of melon seed oil. *J. Sci. Food Agric.* **19**: 615-616 (1968).
22. O.O. Ajibola, S.E. Eniyemo, O.O. Fasina and K.A. Adeeko. Mechanical expression of oil from melon seeds. *J. Agric Engr Res.* **45**: 45 (1990).
23. A.O. Bakhiet. Comparative effects on chicks of some indigenous plants, *Pathology*, University of Khartoum, Khartoum, 1995.
24. J.C. Chen, M.H. Chiu, R.L. Nie, G.A. Cordellb and S.X. Qiu. Cucurbitacins and cucurbitane glycosides: structures and biological activities. *Nat. Prod. Rep.* **22**: 386-399 (2005).
25. A. Delazar, S. Gibbons, R.K. Ali, H. Nazemiyeh, M. Modarresi, L. Nahar and D.S. Satyajit. Flavone c-glycosides and cucurbitacin glycosides from *Citrullus Colocynthis*. *DARU.* **14**(3): 109-114 (2006).
26. R. Mata, P. Castañeda, M. Camacho and G. Delgado. Chemical Studies on Mexican Plants Used in Traditional Medicine V. Cucurbitacin Glucosides from *Cigarrilla mexicana*. *J. Nat. Prod.* **51**(5): 836-839 (1988).
27. D. Nayab, D. Ali, N. Arshad, A. Malik, M.I. Choudhary and Z. Ahmed. Cucurbitacin glucosides from *Citrullus Colocynthis*. *Nat. Prod. Res.* **20**(5): 409-413 (2006).
28. K. Oobayashi, K. Yoshikawa and S. Arihara. Structural revision of bryonoids and structure elucidation of minor saponins from *Bryonia dioica*. *Phytochemistry.* **31**: 943-946 (1992).
29. E.N.T. Akobundu, J.P. Cherry and J.G. Simpsons. Chemical, Functional and nutritional properties of egusi (*Citrullus Colocynthis L.*) seed protein products. *J. Food Sci.* **47**: 829-835 (1982).
30. C.C. Akoh and C.V. Nwson. Fatty acid composition of melon seed oil lipid and phospholipids. *J. Am. Oil Chem. Soc.* **69**: 314-316 (1992).
31. K. Huang, C.C. Akoh and M.C. Erickson. Enzymic modification of melon seed oil: incorporation of eicosapentaenoic acid. *J. Agriculture Food Chem.* **42**(11): 2646-2648 (1994).
32. Z. Yaniv, D. Schafferman, M. Zur and I. Shamir. *Matthiola incana*: Source of omega-3 linolenic acid. In: J. Janick (Ed.), (Progress in new crops. ASHS Press, Arlington, VA, 1996) 368-372.
33. H. Wagner, H.L. Hörhammer and I.C. Kiraly. Flavon-c-glykoside in *Croton zambezicus*. *Phytochemistry.* **9**: 897 (1970).
34. T. Kanchanapoom, R. Kasai and K. Yamasaki. Cucurbitane, hexanorcucurbitane and octanorcucurbitane glycosides from fruits of *Trichosanthes tricuspidata*. *Phytochemistry.* **59**: 215-228 (2002).
35. J. Dahmén and K. Leander. The structure of parishin, a glucoside from *Vanda parishii*. *Phytochemistry.* **15**: 1986-1987 (1976).
36. M. Yoshikawa, T. Morikawa, H. Kobayashi, A. Nakamura, K. Matsuhira, S. Nakamura and H. Matsuda. Bioactive saponins and glycosides: XXVII Structures of new cucurbitane-type triterpene glycosides and anti-allergic constituents from *Citrullus colocynthis*. *Chem. Pharm. Bull.* **55**(3): 428-434 (2007).
37. A.M. Ageel, J.S. Mossa, M. Tariq, M.A. Al-yahya and M.S. Al-said. *Plants used in Saudi folk medicine*. Riyadh: KACST, King Saudi University Press, 1987.
38. D. Lavie and E. Glotter. The cucurbitacin, a group of tetracyclic triterpenes. *Fortschr. Org. Naturstoffe.* **29**: 307-362 (1971).
39. B. Shohat, A.M. Beemer, S. Gitterand and D. Lavie. Antifertility activity of dihydro-elatericin a female mouse. *Cell Mol Life Sci.* **28**(10): 1203-1205 (1972).
40. V.R. Naik, N.V. Agshikar and G.J.S. Abraham. Analgesic and anti-inflammatory activity in alcoholic extracts of *Cucumis trigonus Roxburghii*. *Pharmacology.* **20**: 52-56 (1980).
41. E. Yeshilada, S. Tanaka, E. Sezik and M. Tabata. Isolation of an Anti-inflammatory Principle from the Fruit Juice of *Ecballium elaterium*. *J. Nat. Prod.* **51**(3): 504-508 (1988).
42. H. Eichenseer and C.A. Millin. Maxillary appendages used by western corn rootworms, *Diabrotica virgifera*, to discriminate between a phagostimulant and -deterrent. *Entomol. Exp. Appl.* **78**: 237-242 (1996).
43. D.W. Tallamy, J. Stull, N.P. Ehresman, P.M. Gorski and C.E. Mason. Cucurbitacins as feeding and ovi-position deterrents to insects. *Environ. Entomol.* **26**: 678-683 (1997).
44. L. Dinan, P. Whiting, J.P. Girault, R. Lafont, T.S. Dhadilla, D.E. Cress, B. Mugat, C. Antoniewski and J.A. Lepesant. Cucurbitacin are insect steroid hormone antagonists acting at the ecdysteroid receptor. *Biochem. J.* **327**: 643-650 (1997).
45. I.A. Wasfi, A.K. Bashir, A.A. Abdalla, N.R. Banna and M. Tanira. Anti-inflammatory activity of some medicinal plants of the United Arab Emirates. *Int. J. Pharmacognosy.* **33**(2): 124-128 (1995).
46. I.A. Wasfi. Some pharmacological studies on *Citrullus colocynthis*. *J. Herbs, Spices Med. Plants.* **2**(2): 65-79 (1994).
47. D. Goldfain, A. Lavergne, A. Galian, L. Chauveine and F. Prudhomme. Peculiar acute toxic colitis after ingestion of colocynth: a clinicopathological study of three cases. *Gut.* **30**: 1412-1418 (1989).
48. S. Al-faraj. Haemorrhagic colitis induced by *Citrullus Colocynthis*. *Annual Tropen Parasitology.* **89**(6): 695-696 (1995).
49. A.M. Aly and A. Naddaf. Anti-inflammatory activities of *Colocynthis* topical gel. *J. Med. Sci.* **6**(2): 216-221 (2006).
50. M. Bnouham, A. Ziyat, H. Mekhfi, A. Tahri and A. Legssyer. Medicinal plants with potential antidiabetic activity: a review of ten years of herbal medicine research (1990-2000). *Int. J. Diabetes Metabolism.* **14**: 1-25 (2006).
51. A.I. Abdel-Hassan, A.J. Abdel-Barry and T.S. Mohammeda. The hypoglycaemic and anti-hypoglycaemic effect of *Citrullus Colocynthis* fruit aqueous extract in normal and alloxan diabetic rabbits. *J. Ethnopharmacol.* **71**: 325-330 (2000).
52. H.F. Huseini, F. Darvishzadeh, R. Heshmat, Z. Jafariazar, M. Raza and B. Larijani. The clinical investigation of *Citrullus Colocynthis* (L.) Schrad fruit in treatment of Type II diabetic patients: a randomized, double blind, placebo-controlled clinical trial. *Phytotherapy Res.* Available online at 23 Jan. 2009 (doi: 10.1002/ptr.2754).
53. F. Al-Ghathith, M.R. El-Ridi, E. Adeghate and M.H. Amiri. Biochemical effects of *Citrullus colocynthis* in normal and diabetic rats. *Mol. Cellular Biochem.* **xxx**: 1-7 (2004).
54. N. Sebbagh, C. Cruciani-Guglielmacci, F. Ouali, M.-F. Berthault, C. Rouch, D. Chabane Sari and C. Magnan. Comparative effects of *Citrullus colocynthis*, sunflower and olive oil-enriched diet in streptozotocin-induced diabetes in rats. *Diabetes Metabolism*. In Press (doi:10.1016/j.diabet.2008.10.005).
55. T. Tannin-Spitz, S. Grossman, S. Dovrat, H.E. Gottlieb and M. Bergman. Growth inhibitory activity of cucurbitacin glucosides isolated from *Citrullus colocynthis* on human breast cancer cells. *Biochem. Pharmacol.* **73**(1): 56-57 (2007).
56. T. Liu, M. Zhang, H. Zhang, C. Sun, X. Yang, Y. Deng and W. Ji. Effects of cucurbitacin B on cell proliferation and apoptosis in Hep-2 cells. *Lin Chung Er Bi Yan Hou Tou Jing Wai Ke Za Zhi.* **22**(9): 403-7 (2008).
57. T. Liu, M. Zhang, H. Zhang, C. Sun, X. Yang, Y. Deng and W. Ji. Combined antitumor activity of cucurbitacin B and docetaxel in laryngeal cancer. *Eur. J. Pharmacol.* **587**(1-3): 78-84 (2008).
58. D. Yin, N. Wakimoto, H. Xing, D. Lu, T. Huynh, X. Wang, K.L. Black and H.P. Koeffler. Cucurbitacin B markedly inhibits growth and rapidly affects the cytoskeleton in glioblastoma multiforme. *Int. J. Cancer.* **123**(6): 1364 - 1375 (2008).
59. J.M. Cassidy and M. Suffness. Terpenoid antitumor agents. *Med. Chem.* **16**: 245-269 (1990).
60. D. Lavie, D. Willner and Z. Merenlender. Constituents of *Citrullus colocynthis* (L.) Schrad. *Phytochemistry.* **3**: 51 (1964).
61. P.C. Mali, M. Chaturvedi, A.S. Ansari and V.P. Dixit. Antispermatic effects of an ethanol extract of *Citrullus colocynthis* root in male albino rats. *Pharmaceutical Biol.* **39**(2): 113-119 (2001).
62. M. Chaturvedi, P.C. Mali and A.S. Ansari. Induction of reversible antifertility with a crude ethanol extract of *Citrullus colocynthis* schrad fruit in male rats. *Pharmacology.* **68**: 38-48 (2003).
63. S.W. Quzan, M.M. Almasad and H. Daradk. Short and long effects of *Citrullus Colocynthis* L. on reproductive system and fertility in female Spauge-Dawely rats. *Pak. J. Biol. Sci.* **10**(16): 2699-2703 (2007).
64. F. Dehghani, M. Azizi, M.R. Panjehshahin, T. Talaei-Khozani, and F. Mesbah. Toxic effects of hydroalcoholic extract of *Citrullus colocynthis* on pregnant mice. *Iranian J. Veterinary Res.* **9**(1): 42-45 (2008).
65. U. Memon, A.H. Brohi, W.S. Ahmed, I. Azhar and H. Bang. Antibacterial screening for *Citrullus colocynthis*. *Pak. J. Pharm. Sci.* **16**(1): 1-6 (2003).
66. A.A. Rahuman, P. Venkatesan and G. Gopalakrishnan. Mosquito larvicidal activity of oleic and linoleic acids isolated from *Citrullus colocynthis* (L.) Schrad. *Parasitol. Res.* **103**: 1383-1390 (2008).
67. S. Kumar, D. Kumar, Manjusha, K. Saroha, N. Singh and B. Vashishta. Antioxidant and free radical scavenging potential of *Citrullus colocynthis* (L.) Schrad methanolic fruit extract. *Acta Pharm.* **58**: 215-220 (2008).

68. T. Tannin-Spitz, M. Bergman and S. Grossman. Cucurbitacin glucosides: Antioxidant and free-radical scavenging activities. *Biochem Biophys Res Comm.* **364**: 181–186 (2007).
69. H. Daradka , M.A. Motasem , W.S Qazan, N.M. El-Banna and H.S. Omar. Hypolipidaemic effects of *Citrullus colocynthis* L. in rabbits. *Pak J Biol Sci.* **16**: 2768-2771 (2007)
70. A. Mukerjee, G.B. Shan and N.S. Parmar. Hepatoprotective activity of *Citrullus Colocynthis* extract against CCl₄ induced hepatic damage in albino rat. *Ind J Pharmacol.* **33**: 296-108 (2001).
71. F.H. Diwan, I.A. Abdel-Hassan and S.T. Mohammed. Effect of saponin on mortality and histopathological changes in mice. *Eastern Mediterranean Health J.* **6(2/3)**: 345-351 (2000).
72. F.O. Uruakpa and R.E. Aluko. Heat-induced gelation of whole egusi (*Colocynthis citrullus* L.) seeds. *Food Chem.* **87(3)**: 349-354 (2004).
73. D. Bendjeddou, K. Lalaoui and D. Satta. Immuno-stimulating activity of the hot water soluble polysaccharide extracts of *Anacyclus pyrethrum*, *Alpinia galangal* and *Citrullus colocynthis*. *J Ethnopharmacol.* **88**:155-160 (2003).
74. R.K. Roy, M. Thakur and V.K. Dixit. Development and evaluation of polyherbal formulation for hair growth-promoting activity. *J Cosmetic Dermatology.* (6)2: 108-112 (2007).
75. A. Barth, D. Muller and K. Durling. *In vitro* investigation of a standardized dried extract of *Citrullus colocynthis* on liver toxicity in adult rats. *Exp Toxicol Pathol.* **54(3)**: 223-230 (2002).
76. J.M. Arena and R.H. Drew. *Poisoning, toxicology, symptoms and treatment*, Thomas, IVth Edition, Springfield-II, 1980.
77. M. Habs, S.A.A. Jahn and D. Schmähl. Carcinogenic activity of condensate from coloquint seeds (*Citrullus colocynthis*) after chronic epicutaneous administration to mice. *J Canc Res Clin Oncology.* **108(1)**: 154-156 (1984).
78. A.O. Bakhiet and S.E. Adam. An estimation of *Citrullus colocynthis* toxicity for chicks. *Vet Hum Toxicol.* **37(4)**: 356-358 (1995).
79. F. Dehghani and M.R. Panjehshahin The toxic effect of alcoholic extract of *Citrullus colocynthis* on rat liver. *Iranian J Pharmacol Therap.* **5**: 117-119 (2006).
80. M.A. Al-Yahya, A.H. Al-Farhan and S.E.I. Adam. Preliminary toxicity study on the individual and combined effects of *Citrullus Colocynthis* and *Nerium Oleander* in rats. *Fitoterapia.* **71**: 385-391 (2000).
81. A.A. Al-Qarawi and S.E.I. Adam. Effect of combination of *Capsicum Frutescens* and *Citrullus Colocynthis* on growth, haematological and pathophysiological parameters of rats. *Phytotherapy.* **17**: 92-95 (2003).
82. A.A. Elawad, E.M. Abdel Bari, O.M. Mahmoud and S.E. Adam. The effect of *Citrullus colocynthis* on sheep. *Vet Hum Toxicol.* **26(6)**: 481-485 (1984).
83. M.E. Barri, T.O. Onsa, A.A. Elawad, N.Y. Elsayed, I.A. Wasfi, E.M. Abdel Bari and S.E. Adam. Toxicity of five Sudanese plants to young ruminants. *J Comp Pathol.* **93(4)**: 559-675 (1983).