Tamarindus indica (Caesalpiniaceae)
(Syn.:Tamarindus officinalis, Siliqua arabica)

Engl: Tamarind, Tamarind tree French: Tamarine, Tamarinier
Spanish: Tamarindeiro Portuguese: Tamarinda, jubao
Dutch: Tamarijin German: Tamarinde, Tamarindenbaum
Chinese: Tsao-kiao Tagalog (Philippines): Sampalok

African vernacular names:
Arabian: Humar, thamar hindi, sehbar (Oman), umar (Yemen)
Belgish Congo: Muskishi, tchwa Masai: Ol masambura Shona: Museke, musika
Shambala: mkwazu Sudanese: tomi, utomi Sukuma: Mshishi, mkweso, mkwesu
Swahili: mkwayo, mkwaju
Pharm. definition of the pulp: Pulpa tamarindorum

The plant
A large, evergreen tree, stipules linear, leaves 3.5-15 cm long, paripinnate, leaflets 10 – 20, opposite, 1.2 - 1.8 cm long , 3.75 cm wide, oblong, obtuse. Racemic inflorescences with 10 – 15 pale yellow flowers, pedicels 8 – 10 mm, calyx circa 1.2 cm long, tube turbinate, teeth lanceolate, the lowest two connate. 1 - 3 petals with 1 - 1.5 cm length, pale yellow with red veins. Pods 7.5 – 20 cm long, 2.-2.5 cm wide, slightly compressed, indehiscent. Seeds are dark brown or black.

Plant parts used
The leaves, flowers, bark, pulp of the fruit, seeds

Constituents
From the plant mostly the **pulp** of the fruit is used (Pulpa tamarindorum).
It contains organic acids: Tartaric- (3-10 %), acetic-, citric-, formic-, malic-, succinic acid; amino acids (alanine, leucin, phenylalanine, prolin, serine), invert sugar (25-30 %), pectin, protein (87,9 g/kg), fat (19,1 g/kg), some pyrazines, trans-2-hexenal, and some thiazoles (2-ethylthiazole, 2-methylthiazole) as fragrants (11).
In a bioassay-guided fractionation of a methanolic fruit extract L-(-)-di-n-butyl maleate was isolated. It exhibited a pronounced cytotoxic activity against sea urchin embryo cells (17).
From the tamarind **pericarp** polyphenolic compounds were isolated by semi preparative HPLC. After soxhleth extraction with methanol the total yields were 6.54 g/kg in the **seeds** and 2.82 g/kg in the **pericarp.** The polyphenolics in the **pericarp** are dominated by proanthocyanidins (73.4 %) in form of catechin (2.0 %), epicatechin (9.4 %), procyanindin B2 (8.2 %), procyanidin tetramers till procyanidin hexamers and the flavonoids taxifolin, apigenin, eriodictyol, luteolin, and naringenin. The tamarind **seeds** comprised only procyanidins, represented by their tri - till hexamers, with lower amounts of procyanidin B2 (5.5 %) and -/- epicatechin (4.8 %).
Here one must assume that a part of the polyphenolic substances can be originated by the acid hydrolysis during the extraction. The antioxidant capacities of the soxhleth methanolic extracts were determined. Authors believe them to be an important source of cancer preventive natural products in tropical regions (36).

In the **leaves** of the plant two triterpenes, lupanone and lupeol were found (14).
In the **seeds** polysaccharides are found with a main chain consisting of ß-1,4- connected glucose molecules together with xylose (alpha-1,6) and galactose (ß-1,2), total protein (15 %), lipids with fatty oils and some keto acids (11).

Traditional uses

The young green leaves are used for tasty dishes. The fruits and the isolated pulp of it are components of a drink in Jordan, so called "sous", prepared by infusing T. indica dried pulp. But the hygienic state of it is very poor, containing enterobacteriaceae, especially if not cooled (28).
In the Western Sahel zone of Africa non-cereal plants contribute to the diets of local residents, mainly during times of grain shortage. Tsamiya biri (fruit of T. indica) contains only a moderate portion of protein, below the WHO standard, nor useful amounts of essential fatty acids. It can only supply some diets of the local population (10).
In Western Mali the nutritional importance of green leaves and fruits from T. indica, wild gathered was investigated. Availability and use varied with seasons. Preferentially in rural regions wild gathered foods are used as much as fresh cultivated foods. Green leaves were rich in energy, proteins and minerals. This and other plants are concluded to be valuable and important contributors to the diet of the people living there (20).
In India purified pulp is used against constipation and complaints of the liver and the bile. No dosage is known (11).
In Nigeria T. indica is applied against worm infections, so in Kaduna State against trypanosomiasis in domestic animals and in Bauchi State against guinea worms.

Results of experimental studies

Antibacterial activity

The methanolic leaf extract of T.indica was assessed for antibacterial activity against melioidosis, a life threatening infection common among paddy cultivators in South East Asian countries. In the disc diffusion test the leaf extract showed activity against B. pseudomallei with a MIC and MBC value of 125µg/mL. These in vitro inhibitory potentials suggest further animal studies for the role of T. indica for treating melioidosis (27.
In Puerto Rico 172 plant species, commonly used by the people were investigated for antibacterial activity. Utilizing the disc diffusion method against E. coli and S. aureus, six plants were tested positively. Among these T. indica possessed a strong activity against the tested bacteria (24).
In Yemen ninety crude extracts (aqueous-, methanol-, dichloromethane-) from 30 medicinal plants used to treat common infections were screened in vitro for antibacterial and antifungal effects. Extracts from Tamarindus indica flowers have been the most active (2).

Effects on cells

From the methanolic extract of fruits L-(-)-Di-n-butyl maleate was isolated. It exhibited a pronounced cytotoxicity against sea urchin embryo cell. In comparing structure-activity experiments could be exerted, that this toxicity is connected with the special structure of the chemical. Only L-(-)-Di-n-pentyl maleate was a stronger inhibitor (17).
In the descending colon of Swiss albino mice the fruit pulp caused a greater rate of cell proliferations than in the ascending part, if they were fed a diet of the pulp, compared with the negative controls (34).

A polysaccharide, isolated and purified from T. indica showed immuno modulatory properties like phagocytic enhancement and inhibition of leukocyte migration of the cell proliferation (35).
A phenolic flavonoid from the seed coat extract showed inhibitory effect on the nitric oxide production. In a murine macrophage-like cell line RAW 264.7 and in mouse peritoneal macrophages the extract significantly attenuated the nitric oxide production with 68 %, in a concentration dependent manner. The exposure to the extract had no effect on the cell viability. In safety studies with mice the extract up to 500 mg/kg may modulate nitric oxide production without any overt acute toxicity. In B6C3F1 mice only the highest doses tested (1000 mg/kg) caused a decrease in the body weight without alterations in haematology, serum chemistry or in selected organ weights (18).

Effects on enzymes
From the seeds of T. indica a proteinase inhibitor could be isolated by the ammonium sulphate and acetone precipitation followed by Sephacryl S-300 and Sephadex G-50 gel filtration. It was named PG50, having selective activity. It was strongly active against serine proteinases such as bovine trypsin and isolated human elastase, with an IC50 value 55.96 µg/ml. Cysteine proteinases (papain, bromelain) and serine proteinases (porcine pancreatic elastase, bovine chymotrypsin) were not inhibited. A PG50-fraction showed neither cytotoxic nor haemolytic activity with human blood cells (8).
In an in vitro investigation about insect digestive enzymes from different orders of coleoptera and diptera a proteinaceous inhibitor from T.indica seeds (TTI) showed remarkable activity. In an in vivo bioinsecticidal assay larvae were fed TTI incorporated artificial diets. The concentration of TTI added to cause 50 % mortality (LD50) was 3.2 %.The addition of 4 % TTI addition caused a mortality of approximately 34 % (3).
Neuramidase from Clostridium chauvoei (jakari strain) was reduced in its activity in a dose-dependent manner ($p< 001$) by a partially purified methanolic extract (100 – 1000 µg/mL) from the plant T. indica. The estimated IC50 value was 100 µg/ml. The Km value remained unchanged with 0.42 mM (37).

Treatment of trypanosomiasis and dracunculosis
In Kaduna state of Nigeria a general inquiry was made about the indigenous knowledge for treating trypanosomiasis in domestic animals. Questionnaires and interviews were conducted with about 200 livestock farmers and traders. Between 14 of them used plants. T. indica was encountered (4).
In the traditional medicine of Bauchi State, Nigeria plants are applied against dracunculosis, too. Extracts of leaves were applied topically and resulted in relief of pain, accelerated expulsion of worms and supported the healing (7).

Anti-snake property
In the Indian traditional medicine various plants have been used widely as a remedy against snake bites. In a study the effect of T. indica seed extract was investigated for its pharmacologic and enzymatic activity. Tamarind seed extract inhibited PLA (2), protease, hyaluronidase, l-amino acid oxidase and 5`-nucleotidase enzyme activities of venom in a dose dependent manner. The extract neutralized the degradation of the ß-chain of the human fibrinogen and the indirect haemolysis caused by the venom. The extract prolonged the clotting time moderately, too. Myotoxic effects, like oedema and haemorrhagy, induced by the venom were neutralized significantly when different doses of the extract were preincubated with the venom before the assays. Animals that received extract 10 min after the injection of the snake venom were protected from venom -induced toxicity. The authors recommend the T. indica extract as an alternative for the serum therapy (38).

Pharmacological effects

Antiinflammatory activity
In the traditional medicine of North-African countries many plants are used against inflammation. Using the carrageenan test in rats aqueous-, ethanol-, and chloroform extracts were tested. T. indica showed only a poor activity compared with other plants.

Influence on the blood characteristics and cardiovascular effects
In Bangladesh fruits of T. indica were evaluated for their effects of the lipid profile, systolic and diastolic blood pressure, and the body weight of humans. A diet with dried and pulverized pulp of fruits at a dose of 15 mg/kg body weight reduced the total cholesterol level (p 0.031) and LDL cholesterol level (p 0.004). Neither the body weight nor the systolic blood pressure was influenced. Only the diastolic pressure was reduced (p 0.05) (13).
In hypercholesterolemic hamsters the effect of the crude extract from the pulp was investigated on lipid serum levels and atherosclerotic lesions.
Animals were fed on either usual chow or atherogenic diet during 10 weeks, receiving water or T. indica extract for drinking. The treated animals (5 % pulp extract) decreased in the levels of serum total cholesterol (50 %), non-HDL-cholesterol (73 %) and triglyceride (60 %). They increased in the high-density lipoprotein (HDL) cholesterol levels (61 %). As assessed by the superoxide dismutase, catalase and glutathione peroxidase assay, the extract improved the efficacy of the antioxidant defence system. According to these results the authors argue that the tamarind extract has a high potential in diminishing the risk of atherosclerosis in humans (23).
In hamsters the hydroalcoholic extract of tamarind pulp influenced the mediator system of inflammation, too. Hamsters fed a diet rich in cholesterol were treated with the extract. They showed values of processes preceding inflammation similar to those of the controls. The treatment with the extract blocked the increasing activity caused by the cholesterol diet, therefore. The authors believe that these results may be of interest for therapeutical uses and research purposes (19):

Antidiabetic effects
In the Indian traditional system of medicine herbal remedies are prescribed for diabetes mellitus, too. An aqueous extract from T. indica seeds had a potent antidiabetogenic activity in streptozotocin induced diabetic male rats. The supplementation of this water extract at the dose of 80 mg/0.5 ml in distilled water/100g body weight per day to diabetic rats diminished the fasting blood sugar level after 7 days. Further supplementation for 14 days gave no significant differences to the controls. Moreover, this supplementation raised significantly the glycogen content in the liver and skeletal muscles and the activity of liver glucose-6-phosphate-dehdrogenase in respect to the control levels. Other enzymes of glucose metabolism in the liver were lowered significantly in the extract supplemented group. All these parameters were not resettled after 7 days, but after 14 days they were restored to the control level (22).
The aqueous extract of T. indica seeds was given to mild diabetic and severe diabetic rats at the dose of 80 and 120 mg//0.5ml distilled water /100g body weight daily for 14 days. Hyperglycaemia was significantly attenuated, measured by fasting the blood glucose levels. Similarly, hyperlipidemia was reduced measured by different contents of cholesterol. This rat model may shed some light on the basis of ancient herbal therapy in India; argue the authors (21).

Effects with hens
30 hens of different strains (5 hens per strain) 43 weeks old were fed diets supplemented with 0 (control), 2, 4, 6, and 8 % oven-dried tamarind pulp for 6 weeks. The egg production, egg mass, and feed utilization were measured in animals fed with a minimum diet of 2 % and a maximum diet of 8%. There were no differences in the results between the strains following

these parameters ($p>0.05$). The yolk weight increased linearly ($p>0.05$) with increasing levels of tamarind, in weeks 1, 2, and 3, as well as when averaged over 6 weeks. Egg yolk cholesterol concentrations were not affected by the dietary tamarind. Serum cholesterol concentrations decreased with the increasing levels of the tamarind ($p<0.05$).
It was concluded that 2 % supplemented tamarind could decrease serum cholesterol concentrations and increase the layer performance (6).

Technical aspects of tamarind pulp and kernels
Tamarind seed powder obtained after removing the fruit pulp from tamarind fruit pod was tested for the production of tannase, using Aspergillus niger fungus:
In a TSP medium the maximum tannase yield of 644 IU was obtained at 30° C, with 65.75 % initial substrate moisture, 1 % glycerol, 1 % potassium nitrate, $11x10^9$ spores /5g substrate inoculum, after 120 h of fermentation.
In a PKC medium the maximum enzyme yield of 13.03 IU/g dry substance was obtained at 30° C, 53.5 % initial moisture, $33x10^9$ spores/5g substrate inoculum, and 5 % tannic acid after 96 h of fermentation.
These results seem promising for the economic utilisation of agro residues like tamarind residues, which are abundantly available in many tropical countries (33).
Because of its adsorptive properties low cost masses of tamarind seeds, of the pulp and of the mucilage, derived from them all are able to clean polluted water.
For the industrial and domestic cleaning of water the absorption of fluoride was investigated with a positive effect (25).
In another case tamarind was used to help in delaying progression of fluorosis in school children by enhancing urinary excretion of fluoride (15,16).
The absorptive capacity of tamarind seeds for excretion of chromium IV was assayed with down flow columns. The result of absorption was quite good (1).
Finally, the polysaccharides from the seeds are used as raw material for preparing tablets (11).

Results of clinical studies

Effects on the bioavailability of medicines
Six healthy human volunteers are given Ibuprofen tablets 400 mg in a meal together with T. indica fruit extract. Control persons, being in fasting state are given a meal without fruit extract. There was a statistic increase in the plasma levels of Ibuprofen and its metabolites hydroxyibuprofen and carboxyibuprofen. There was no change in T-max (120.00 +/- 0.43 min). But there was a decrease of elimation from 0.63 +/- 20 to 0.46 +/- 0.11 per hour.
One can conclude that T. indica significantly increased the bioavailability of Ibuprofen (9).

In a similar case the bioavailability of aspirin was investigated. There was a significant increase in the plasma levels of aspirin and salicylic acid, when the meal contained T. indica fruit extract and was administered with the tablets, compared with a meal without fruit extract. There was no change in T-max (0.50 +/- 0.17 h), but there was a decrease in elimination from 0.633 +/- 0.22 to 0.463 +/- 0.29 ($p<0.05$). The bioavailability increased here, too (26).
The bioavailability of chloroquine is influenced by common Sudanese beverages coadministered with 600 mg tablets. One of them, Aradaib, was prepared with T. indica.
The results show a significant reduction of the plasma concentration and the T-max of chloroquine. A parallel reduction in the antimalarial efficacy of the drug must be expected, therefore (20).
Tamarind kernel powder (TK) was evaluated for its suitability as a carrier to improve the dilution rate of celecoxib (CC), a drug, poorly soluble in water. The co-grinding technique of CC and tamarind kernel powder in a preparation ratio 1:4 (CC / TK) made the dilution rate suitable from a practical point and commercial use (5).

The tamarind seed polysaccharide (TSP) possesses mucomimetic, mucoadhesive and pseudoplastic properties. The mucin-like structure of it is similar to the corneal and conjunctival mucin 1, which wets and protects the corneal surface.
In an open randomised single-centre study for the treatment of dry eye syndrome the activity of TSP was compared with hyaluronic acid (HA). Thirty randomised patients received three or more applications of either TSP 0.5 % or hyaluronic acid 0.2 % per day. The endurability, the incidence of adverse events, the stability of corneal film and subjective symptoms were tested.
The TSP 0.5 % and 1 % values were comparable to HA 0.2 %. The TSP 1% value showed benefits over HA 0.2 % concerning subjective symptoms like trouble blinking, ocular burning and foreign body sensation. The authors suggest that TSP 0.5 % and 1 % offer an equivalent relief to HA 0.2 % for the dry eye syndrome and may be suitable for the frequent use in the therapy of dry eye syndrome. But nothing is said about the bacterial content of the solutions being used over longer times, especially in the tropical climate (32).
Corneal derived cells (SIRC) were exposed for 9 s to a UV-B source in the absence or in the presence of the T. indica polysaccharide (TSP).The exposed cells accumulated H_2O_2, have higher levels of 8-hydroxy-2`-deoxyguanosine and a lower amount of (3)H-methyl-thymidine than the controls.
In the presence of TSP these effects were reduced significantly with respect to the values of the cells exposed without TSP. This finding could be of clinical importance, when the polysaccharide is used as a delivery system for ophthalmic preparations. (30).

Investigations about gallstones
Pigment- or mixed gallstones are common in Southern India. The reasons are not known.
The aim of an investigation was to determine the association of the dietary factors of such gallstones with the dietary factors of Southern Indian patients.
Data were obtained from 346 patients (178 women) with gallstones and an equal number of healthy controls. There was no difference between cases and controls in the consumption of non-vegetarian food, type of cereal, average oil and sugar consumption and the type of beverages consumed.
Individuals with Body Mass index >22 were at higher risk to develop gallstones ($p=0.01$). There was a significant risk of gallstone formation with the use of tamarind when consumed 3 times a week or more ($p<0.03$). Higher BMI indices and the use of tamarind, a common ingredient of diet in Southern India, are risk factors in the formation of gallstones (12).

Evaluation
Since old times the pulp of tamarind is used because of its adsorptive properties e. g. in the treatment of constipation. This property can be responsible for retention of medicines in the metabolism of humans like aspirin, ibuprofen and chloroquine, too. It can cause a raised bioavailability. But there was no exact information about the dosages. One must argue against coadministration of pulp and medicines, therefore.
The mucins in the tamarind seeds were tested in a clinical trial. They show benefits as eye drops, but in the tropical climate antibacterial substances must be added, as it is usual for all eye drops.
For the manifold effects with cells, enzymes, and blood the polyphenols may be responsible. They can cause manifold complaints in the organisms like animals and humans. Therefore they cannot be applied, generally.
Mixtures with extracts of different plant parts can be used as bioinsecticides.
The content of triterpenes in the leaves seems to be very small because they are eaten as vegetables. There are no reports with bad or fatal results.

Tamarindus indica

against constipation	***
as an bioinsecticide	***
as eye drops	**
green leaves as vegetables	***
in coadministration with medicines	- - -

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