BIOLOGY, MEDICINE, & NATURAL PRODUCT CHEMISTRY ISSN 2089-6514 (paper)
Volume 12, Number 1, April 2023 | Pages: 205-213 | DOI: 10.14421/biomedich.2023.121.205-213 ISSN 2540-9328 (online)

Bioactive Compound in *Solanum torvum* and Its Potential as Functional Food and Drink: A Review

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Manuscript received: 11 October, 2022. Revision accepted: 12 February, 2023. Published: 15 February, 2023.

Abstract

Solanum torvum is a fruit used as food and has medical properties. This study aims to provide an updated understanding of *Solanum Torvum's* health benefits as a functional food through a study literature review. The research utilizes electronic databases (PubMed, Science Direct, Scopus, Nature, Clinical Key, and Springer) from July-October 2022. *Solanum Torvum* contains various bioactive components, vitamins, mineral, nutritions. It shows that *Solanum torvum* has potential sources as functional food. However, studies about *solanum torvum* consumption as a functional food and the clinical trial of its health benefits in humans are still limited. Further in vivo and in vitro studies are necessary to present the effect of *solanum torvum* consumption on health.

Keywords: *Solanum torvum*; antioxidant; bioactive compound; nutrition; functional food and drink.

INTRODUCTION

The body's immune system uses the involuntary primitive reflex of coughing to defend against foreign substances that invade the respiratory tract (Sharma et al., 2020). To eliminate debris, excessive mucus, irritants, microbes, or other substances from the respiratory tract, one may cough either voluntarily or involuntarily. Coughing is either voluntary or involuntary (Chung and Pavord, 2008).

Solanum torvum has various local names in Indonesia, it has known as Pokak (East Java), Cepoka (Central Java), Takokak (West Java), Rimbang (Sumatra and Melayu), Terong pipit, and many more (Zuhud, 2003). It is also called Turkey Berry, Devil's fig, cherry eggplant, water nightshade, or wild eggplant (Lim, 2013). In 1964, Lawrence classified *Solanum torvum* into taxonomical classification.

Kingdom	: *Plantae*
Division	: *Spermatophyta*
Sub Division	: *Angiospermae*
Class	: *Dicotyledonae*
Order	: *Solanale*s
Family	: *Solanaceae*
Genus	: *Solanum*
Species	: *Solanum torvum Swartz*

Distribution of *solanum torvum* to growth could reach tropical and subtropical territories throughout the world (West and Central Africa, Indian subcontinent, Southeast Asia, China, Japan, Australia) and many Pacific Islands; in the western hemisphere such as Mexico, Central America, Greater and the Lesser Antilles, South America (Brazil, Ecuador, French Guiana, Guyana, Venezuela), the United States to the Caribbean (Scher *et al.*, 2015). The good habitat for species to grow in moist, fertile soil and will tolerate drought; wet thickets, dry brushy plains, woodland clearings, rocky hillsides; weeds in pastures, open native vegetation, swamps, roadsides, and waste places (Scher *et al.*, 2015). On the other hand, 1-3 kilogram fruits could be produced from a single tree of *Solanum torvum*. This plant can produce fruit in 5-8 months from the start of the plantation (Pratiwi, 2012).

This plant is a nutritious food resource in Africa that significantly contributes to massive societal nutrition because it has abundant minerals (Okoto, 2015). In traditional folkloric medicine, *Solanum Torvum* has been used as an antipyretic, anti-rheumatic, anti-infectious, anti-inflammation, diuretic, and analgesic (Burkill, 1966; Burkill, 2000; Jain & Borthakur, 1986; Stuart, 2022). In modern pharmacological studies, *Solanum Torvum* shows antioxidant activity (Waghulde, 2011; Gyamfi, 1999), antifungal activity (Karuppusamy, 2009; Beg et al., 2002), antibacterial activity (Satish, 1999; Lalitha, 2010), antiulcer activity (Telesphore, 2008; Antonio, 2004), antihypertensive and metabolic correction activity (Nguelefack, 2008; Jaiswal, 2012; Lim, 1992), nephroprotective activity (Waghulde, 2011; Vaclavikova, 2008; Mohan, 2010), cardioprotective activity (Mohan,

2009), antidiabetic activity (Gandhi, 2011; Keisuke, 2010), analgesic and anti-inflammatory activity (Ndebia, 2007; Atta, 1997), immunomodulatory and erythropoietic activity (George, 2011; Israf, 2004).

Not only used for medical purposes but *Solanum Torvum* also could be used as a food or drink product to get the essential benefit for human health (Jaiswal, 2012). Recently studies revealed that *Solanum torvum* contains a very potent antioxidant and other useful phytochemistry components (Helilusiatiningsi, 2021). The currently popular idea of creating food to get a healthy purpose is called functional food. Functional foods are foods that provide health benefits beyond its nutritional value. This paper aims to provide an updated review of the phytochemicals compounds on *solanum torvum* by promoting its opportunity as a functional food to improve human health.

Parts and Nutritional Value of *Solanum Torvum*

Figure 1. *Solanum Torvum.*

Solanum torvum trees could grow up to 2 to 4 meters in height with an ideal environment to grow under full sunlight or partially in shades (Pratiwi, 2012). Its habitat is commonly found on roadsides and in disturbed soils, with expected growth as an individual plant. Commonly found up to an altitude of 1600 m and suitable in moist soil conditions. Young and immature fruits are consumed raw, cooked as a vegetable or used as an ingredient in curry sauce. In Indonesia, *Solanum torvum* is considered one of the best side dishes to go along with rice as a vegetable called lalapan (Lim, 2013). Each part of this fruit contains a lot of benefits.

Plant parts	Description and nutritional values
Fruits and seeds	The fruit is a spherical round shape berry and has diameter about 1.0 to 1.15 cm. Each fruit has about 300 to 400 flat, brown dark seeds inside. Berry seeds of medium size (around 1,5 mm long) are hard to distinguish from one another. The fruit color may be affected by aging and the length of the lifetime spent (Sirait, 2009). The fully ripped berry has yellow skin, and the youngberry has green with glossy color (Scher *et al.*, 2015). The flowers are bisexual. The plant flowers throughout the year. Heavy rainfall discourages fruit growth and set (Singapore Government Agency, 2022). Extract of the fruit revealed the number of alkaloids, flavonoids, and certain fatty acids such as palmitic and oleic tested analysis by the GC-MS instrument (Jaabir, 2015). Extraction from seeds of *Solanum torvum* showed a significant amount of phenolic and flavonoid contents which could be the source of natural antioxidants (Waghulde, 2011). In pharmacology, alkaloids and solasodina compounds that contain in the fruit can be used as substrates for the production of the important steroid (Perez-Amador et al. 2007). In addition, the fruit also contains many solosin, chlorogenin, sisalagenone, tervogenin, protein, fat, calcium, phosphorus, iron, vitamins A, B1 and C (Zuhud et al. 2003).
Leaves	*Solanum torvum* leaves have a large and green shape with a leaf length range of about 10-15 cm and a width of 8-10 cm. (Jaiswal, 2012). The leaves are simple and ovate to elliptical in shape and lobed. The surface is pubescent. Phytochemical analysis revealed the presence of 32 chemical constituents, mainly phenolic compounds, terpenoids, palmitic acid, palmitic acid ester, linoleic acid, linolenic alcohol, linolenic acid ester, and stearic acid found in *Solanum torvum* leaves (Naimon et al. 2015). The leaves can be dried, mixed, and added to hot water to

Plant parts	Description and nutritional values
	make a cold or cough medicine (Yousaf *et al*., 2013).
Roots and stems	*Solanum torvum* is a prickly shrub or small tree, up to 5 m tall. It is cultivated in the tropics for its sharp-tasting, immature fruits (Scher *et al.*, 2015). In Malaysia, the seeds are smoked to treat toothaches, while the roots are applied as a poultice to treat foot cracks. In China, the roots are believed to disperse blood that has leaked into the surrounding tissue and relieve pain. In India, extracts of the plant are used as an antidote to insect stings, and the fruit is eaten to relieve stomach aches). Root powder of the fruit can be used as a remedy for leg fractures and headache relief and can be used as asthma treatment and liver therapy (Yousaf et al., 2013). It is reported that *Solanum torvum* roots contain secondary metabolites (Sivapriya, 2011). These are potential sources of antimicrobials such as steroid alkaloids, saponins, flavonoids, glucosides, and tannins (Bari *et al.,* 2010).

THE PHYTOCHEMICAL COMPOUNDS AND ANTIOXIDANT OF SOLANUM TORVUM

Native to and cultivated in Africa and the West Indies is Solanum torvum Sw. (Solanaceae), sometimes known as Turkey Berry (Adjanohoun, 1996). Due to their antioxidant characteristics, fruits and leaves are commonly employed in traditional Cameroonian medicine. Numerous substances found in Solanum torvum have the potential to have pharmacological effects, including isoflavonoid sulfate, steroidal glycosides, chlorogenic and neochlorogenone, triacontane derivatives, 22--O-spirostanol oligoglycosides, 26-O-glucosidase (Arthan, et. al., 2006). This plant has secondary metabolites in its leaves, stems, and roots, including steroidal alkaloids, saponins, flavonoids, glucosides, and tannins, which make it a robust and potentially antibacterial source (Bari at al., 2010; Sivapriya et al., 2011). Pérez Amador et al. (2017) measured the overall alkaloid content (0.12%), total glycoalkaloids (0.038%), and the glycosylated compounds produced from solasodine, namely solasonine (0.0043%) and solamargine (0.0028%). The amounts of polyphenolic substances (phenols, flavonoids, and tannins) were measured to be 160.30, 104.36, and 65.91 mg/g, respectively (Kusirisin et al., 2009). In ethanolic extracts of immature and mature fruits, alkaloids, total saponins, total flavonoids, and vitamin C contents were compared (Koomson et al. 2018), and only alkaloids were found to be significantly different (respectively, 16.94 2.3 mg/g in the immature fruits, and 6.32 0.12 mg/g in mature fruits).

A large amount of reactive oxygen or as known as free radicals, that the human body produces and receive creates an urgency to develop and have large sources of antioxidant to tackle with. Syntethycally antioxidants (for example, butylated hydroxyl anisole, gallic acid ester, butylated hydroxyl toluene, etc.) are associated with the side effect on human health (Gao, 1999). Synthetic antioxidants show a small level of solubility and a medium level of antioxidant activity (Barlow, 1990) The substitution of synthetic antioxidants could be produced by utilizing natural resources from plants (Waghulde, 2011).

Antioxidant activity from plants has a correlation with phenolic compounds (Cook, 1996). Flavonoids are a group of polyphenol compounds with known properties, including free radical scavenging, inhibition of hydrolytic and oxidative enzymes, and anti-inflammatory activity (Frankel, 1995). Wahluge *et al*, 2011 analyze the antioxidant activity, phenol, and flavonoid contents of seeds of *Punica Granatum* and *Solanum Torvum*. the result showed that the highest radical scavenging activity was observed with *solanum torvum* extract, with a significant linear correlation with phenolic and flavonoid contents.

Antioxidants are compounds that protect compounds or tissues from the damaging effects of oxygen or the effects of oxidation. According to Kumalaningsih (2006), antioxidants are compounds with molecular structures that can donate electrons to free radical molecules and cut free radical chain reactions. In other words, antioxidants are able to work as inhibitors that try to inhibit oxidation by reacting with reactive free radicals to form relatively stable non-reactive free radicals. However, when combined with free radicals that can cause disease, antioxidants are defined as compounds that protect the body from the harmful effects of reactive oxygen free radicals (Sofia, 2016).

Saponins is a glycoside group of compounds can be found in plants naturally and has unique properties, such as soap that can produce foam when shaken in the air. Classified as a polar compound, this compound is soluble in air and is able to work as an antioxidant component to reduce free radicals in the body, so it can be used as a compound to prevent oxidative stress in liver cells (Mardiningsih et al, 2010). **Tanins is c**lassified as a complex polyphenolic compound, tannins can bind proteins well. The molecular weight is about 500-3000 Da. These compounds can also be classified as hydrolysable tannins and condensed tannins. The molecular structure of hydrolyzable tannins is the hydroxyl of esterified phenolics such as gallic acid. Tannins also have an anti-oxidant effect (Ismarani, 2012). *Solanum torvum* extraction using aquades as a solvent showed the content of alkaloids and tannins (Alfarabi et al, 2018). Phenolics has high antioxidant capacity due to ability to pass hydrogen on to extremely reactive radicals, therefore preventing further radical

formation (Lapornik et al. 2005; Xu et al. 2007). **Flavonoid** are natural active phenolic compounds with a C5-C3-C6 chemical structure. This compound is often found in green plants and is useful as a source of antioxidants that can reduce free radicals or oxidation in the body. Flavonoids are also inflammatory agents (Rompas et al., 2012). Flavonoids have a major role in analgesic activity (Acharyya et al., 2018).

Elements to Analyze	Amount	Benefit	Ref
Macronutrients Content (g/100g)			
Total carbohydrates	71.42 ± 0.52	▪ combined with dietary fiber are generally recommended to prevent atherosclerosis, constipation and diseases in the intestine such as appendicitis and colon cancer (Melila, *et.al*, 2021)	(Melila, *et.al*, 2021
Protein	16.49 ± 0.47	▪ can use in human food can contribute to the fight against protein-energy malnutrition	
Fat	7.71 ± 0.19	▪ anti-hypertensive diets	
Ash	4.65 ± 0.46	▪ mineral components	
Water content (%/100g)	79.28 ± 0.06		
Energy (Kcal/100g)	421 ± 2,01		
Minerals (mg/100g)			
Sodium (Na)	155.2 ± 44.37	▪ involved in the transmission of nerve impulses and in the water balance of the body (FAO, 2004)	(Melila, *et.al*, 2021; Kouadio et al., 2020)
Potasium (K)	1307 ± 433.7	▪ involved in muscle contraction (FAO, 2004)	
Phosporus (P)	78.70 ± 20.10	▪ necessary for the formation of the skeleton. ▪ essential in the processes of energy storage in the body in the form of ATP (Kemi *et al*., 2006)	
Calcium (Ca)	38.45 ± 8.54	▪ necessary for the formation of the skeleton. ▪ involved in muscle contraction (FAO, 2004) ▪ can be used in diets aimed at skeletal formation (Kemi *et al*., 2006) ▪ balancing the body's pH by neutralizing excess acids (Kemi *et al*., 2006)	
Magnesium (Mg)	38.45 ± 8.58	▪ trace element that stimulates the immune system, protects against cell aging and maintains fatty tissue (Kala, 2005) ▪ the production and oxygenation of blood cells, digestion and blood circulation (Abbaspour, *et al.*, 2014) ▪ involved in muscle contraction (FAO, 2004) ▪ essential cofactor of the enzymes of carbohydrate metabolism (Fiorentini, 2021)	
Iron (Fe)	21.04 ± 0.68	▪ the production and oxygenation of blood cells, digestion and blood circulation (Abbaspour, *et al.*, 2014)	
Zinc (Za)	14.65 ± 2.69	▪ trace element that stimulates the immune system, protects against cell aging and maintains fatty tissue (Kala, 2005) ▪ the production and oxygenation of blood cells, digestion and blood circulation (Abbaspour, *et al.*, 2014)	
Vitamin (mg/100g)			
Vit C	2.44 ± 0.36	▪ defense of the body against virus and bacterial infections, ▪ the protection of the blood vessel wall, ▪ the assimilation of iron and has an important antioxidant activity(Carr, 2019)	(Melila, *et.al*, 2021;
Vit A	0,078	▪ helpbody's natural defence against illness and infection (the immune system) work properly. ▪ helping vision in dim light (Duester, 2000)	(Okoto, 2015)
Phytochemical contents (mg/100g)			
Polyphenols	356.70±0.02	▪ anti-inflammatory, urinary antiseptic, anti-free radical, hepatic-protective, immune stimulant, anti-thrombotic and anti-carcinogenic effects	(Kouadio et al., 2020; Vauzour, 2010; Acho, 2014)
Phenol	160.30+3.00	▪ oral analgesic, antioxidant, anti-inflammatory, anti-allergic, anti-carcinogenic, antihypertensive, cardioprotective, anti-arthritic and antimicrobial activities (Bhuyan, et al., 2017)	
Tannins	685.83±0,01	▪ anti-nutritional compounds that have deleterious effects on digestibility	
Flavonoids	104.36+3.00	▪ regulate cellular activity and fight off free radicals that cause oxidative stress on human body (Kusirisin, 2009)	(Kusirisin, 2009)
Antioxidant Activity	360.53+5.06	▪ protection against damage caused by free radicals (Kusirisin, 2009)	

Value Added as Functional Foods and Drinks from *Solanum Torvum*

The wide traditional medicinal use of S. torvum fruits is nowadays explained by the production of many phytochemicals by this species. Alkaloids, flavonoids, tannins, saponins, and glycosides are present in S. torvum extract in sufficient concentrations for protecting the body against oxidative stresses. S. torvum can therefore be considered a promising natural source of phytochemicals displaying a range of medicinal properties, ranging from cardio protection & treatment of heart related diseases, nephro-protection, to analgesic, anti-inflammatory, anti-ulcer, and anti-microbial activities.

Solanum Torvum is having a huge potential resource for developing food products. It's containing a number of nutritional values, bioactive components, and other physicochemical properties. The fruit's nutritional content could be used as based ingredients or substitute materials to increase the nutrition in food (Helilusiatiningsi, 2021). If the Turkey berry fruit is used optimally by the community, then the fruit will be an alternative treatment that is cheap, easy, and relatively safe. It's easy because the plant grows and can be found around the community and people can cultivate it themselves at home. The cost of processing the fruit will be much cheaper than treatment with chemical drugs. In addition, traditional medicines that tend to have no side effects are relatively safe for people to use (Pratiwi, 2012).

Flour (dried powder)

The most common commercially used product, dried fruit powders are found to be an emerging functional ingredient. It has a long shelf life because of the water content and odorless materials (Phan, 2021). To make it efficient to combine with other food products, it is necessary to create *Solanum torvum* powder. Helilusiatiningsih, 2021 identifies the phytochemistry component of *Solanum Torvum* flour by doing 3 different methods of drying.The types of methods are sunlight drying, vacuum dryer, and try dryer. The result explains phytochemistry compounds and nutritional values.

The vacuum drying method showed a higher DPPH of 92.81% compared with the try drying method, which has 85.15%, and the sunlight drying method, which has 88.10%. The antioxidant activity of phenolic compounds was attributed to their ability to scavenge free radicals, giving hydrogen atoms, electrons, or chelate metal cations (Afanas'ev, 1989). Phenol compound is higher found in vacuum drying method (92.8 mg/g) than in sunlight method (37.32mg/g) and the try drying (22.91 mg/g).

Tannins are phenolic compounds of high molecular weight ranging from 500 Da to more than 3000 Da they are found in plants, and their parts are located in the tissues, specifically in the vacuoles (Hassanpour, 2011). Higher tannin content for the flour was found in the vacuum drying method (1.24 mg/g), followed by the sunlight method (1.03 mg/g), and try drying (0.63 mg/g). Different from DPPH, phenol, and tannins, a higher amount of flavonoids was found in the sunlight method (5.11 mg/g), followed by the vacuum drying method (2.75 mg/g), and try drying method (2.43 mg/g). Proximate analysis shows quantitative analysis of macromolecules in food. To compare the nutritional values of the flour, the results were summarized in Table 1.

Table 1. Nutritional values of the Solanum Torvum flour with different drying methods.

Proximate analysis parameter	Drying method		
	Sunlight drying	Vacuum drying	Try drying
Water content (%)	6.92	7.62	6.89
Ash Content (%)	3.66	2,82	3,29
Protein (%)	11, 51	22.66	21.28
Fat (%)	5.38	3.25	7.04
Carbohydrates (%)	72.53	65.51	61.5
Vitamin C (%)	0.21	2.44	0.39

Source: Helilusiatiningsih, N. (2021)

Tea

Teye, (2017) developed functional drink combination from roselle (*Hibiscus Sabdarffa*), ginger (Zingiber officinale), and turkey berry (*Solanum torvum*). Among several samples, 50% roselle + 25% ginger + 25% turkey berry shows optimum protein content (4.14%), Ca (1.80%), Fe (0.96 µg/g) and Cu (1.18 µg/g). It also showed the best performance for sensory evaluation in terms of color, aroma, flavor, aftertaste, and overall acceptability.

Furthermore, Helilusiatiningsih (2021) developed *Solanum Torvum* fruit extract as a potential healthy drink with a combination of black tea and green tea. According to the result, most panelists preferred Black tea *Solanum torvum* to green tea *Solanum torvum* by organoleptic test on aroma, taste, and color. A qualitative test shows that black tea *Solanum torvum* contains bioactive compounds, such as saponins, glucosides, steroids, and alkaloids. Sample also shows amount of carbohydrates (63,96±0,08%), fat (9,67±0,05%), protein (24,76%), ash content (3,08 ±0,05%), moisture content (6,39 ± 0,12%), vitamin C (6,20±0,05%), and minerals (Ca (38,34 ppm), Mg (76,3 ppm), Fe(4,51 ppm).

Snack Bar

Novilia, 2017 investigated the food processing of *Solanum Torvum* in the Snack bar. The investigation focused on the production of *solanum torvum* flour making, formulation and production of the snack bar, organoleptic testing, analysis of nutritional content, fiber, total phenolic compound, and antioxidant activity on the product. Among several samples, 10% extract of *solanum torvum* showed the best organoleptic test and nutrition content, such as moister content (10.30%), ash

content (1.35%), protein (9.70%), fat (19,57%), carbohydrates (36.8%), fiber (22.28%), total phenolic (0.47%) and antioxidant activity equivalent vitamin C (704.14 mg/100 g). Thus, the analysis of the contribution of nutrients in 1 serving size (37 g), *solanum torvum* bar contributes energy (5.95%), protein (6.78%), fat (12.21%), carbohydrates (6.30%), dietary fiber (36.54%) and total phenolic (174 mg/37 g) for general nutrition advice.

Noodle

Atika et al. (2021) found that *Solanum torvum* extract could be used as an additional ingredient in noodles. Adding *solanum torvum* extract in noodles improves the product with vitamin A. In plants, vitamin A has been found as provitamin A; the most active form of this vitamin is β-carotene. This component prevents vitamin A deficiency, where cells and tissues could be damaged in the human body. Furthermore, the researchers discovered that adding s*olanum torvum* with 85% of flour, 75% of *Solanum torvum*, and 40% of water could develop the β-carotene component to 671.2548 g/100g. The control sample with 100% flour and 100% water without *Solanum torvum* fruit extract could only reach 140.8604 g/100g. β-carotene content of 671.2548 g/100g is equivalent to 111.8758 RE when associated with the nutritional adequacy rate for vitamin A.

Juice

In Ghana, the fruits of *Solanum Torvum* are traditional healers for anemia and ailments. The fruit is processed into a drinkable juice. With a high concentration of iron, it is possible to be utilized as a healing treatment for anemia and iron deficiency. Iron is a mineral needed for human growth (Al-Jameil *et al*., 2014). *Solanum torvum* aqueous extract has the ability as immunomodulatory and haematinic properties where it could be used as a hematinic and food for patients with immunity problems (Koffuor, 2011). A study by Okoto (2015) investigated the components of *Solanum Torvum* Juice. The analysis shows that fruit juice has an abundance of water content (86,23%), carbohydrates 7.033%, proteins 2.322%, fats 0.278%, ash 0.143%, and crude fiber 3.993%. The analysis for important minerals content was conducted. According to the obtained results, Calcium was the highest amount of mineral (221.583 mg/kg), followed by Iron (76.869mg/kg), Zinc (21.460mg/kg), manganese (19.466 mg/kg), and copper (2.642mg/kg). Besides nutritional and mineral compounds, vitamin was found in the juice. The 100 grams of the sample contain 2.686 mg of vitamin C and 0.078 of Vitamin A.

CONCLUSIONS

Solanum Torvum contains various bioactive components, vitamins, mineral, and nutritions. It shows that *Solanum torvum* has potential sources as functional food. However, studies about *solanum torvum* consumption as a functional food and the clinical trial of its health benefits in humans are still limited. Further in vivo and in vitro studies are necessary to present the effect of *solanum torvum* consumption on health.

Competing Interests: The authors declare that there are no competing interests.

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