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ORIGINAL ARTICLE

Chemical Composition and Biological Activity of *Physalis peruviana* L.

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Abstract

Physalis peruviana L. belongs to the family Solanaceae and is considered as plant used for treating various diseases. The protective mechanism of Physalis consists of the ability to scavenge reactive oxygen species (ROS) and to enhance the antioxidant system in the human body. The ethanolic extract of *Physalis peruviana* fruits contains valuable and active compounds such as carotenoids, phenols, flavonoids, tannin, alkaloids, vitamins C, B3 and B6. Therefore, *Physalis peruviana* extract has antioxidant and antimicrobial activity against gram-positive and gram-negative bacteria. Gram-positive *Bacillus cereus* demonstrated higher susceptibility than gram-negative *Escherichia coli* and *Pseudomonas typhimureum*. Also, the extract showed positive effect on the fungus used (*Aspergillus niger* and *Candida albicans*). In addition, high concentrations of *Physalis peruviana* ethanolic extract (800 µg/ml) exhibited significant anticancer activity against lung (A549) cells but slight effect against colorectal adenocarcinoma (Caco-2) cells.

Keywords Physalis peruviana · Phenols · Flavonoids · DPPH · Anticancer activity

Chemische Zusammensetzung und biologische Aktivität von *Physalis peruviana* L.

Zusammenfassung

Physalis peruviana L. gehört zur Familie der Solanaceae und gilt als Pflanze, die zur Behandlung verschiedener Krankheiten eingesetzt wird. Der Schutzmechanismus der Physalis besteht in der Fähigkeit, reaktive Sauerstoffspezies (ROS) abzufangen und das antioxidative System im menschlichen Körper zu verbessern. Der ethanolische Extrakt der *Physalis peruviana*-Früchte enthält wertvolle und aktive Verbindungen wie Carotinoide, Phenole, Flavonoide, Tannine, Alkaloide, Vitamin C, B3 und B6. Daher besitzt der Extrakt von *Physalis peruviana* eine antioxidative und antimikrobielle Aktivität gegen grampositive und gramnegative Bakterien. Grampositive *Bacillus cereus* zeigten eine höhere Empfindlichkeit als gramnegative *Escherichia coli* und *Pseudomonas typhimureum*. Außerdem wies der Extrakt eine positive Wirkung auf den verwendeten Pilz (*Aspergillus niger* und *Candida albicans*) auf. Darüber hinaus zeigten hohe Konzentrationen des ethanolischen Extrakts von *Physalis peruviana* (800 µg/ml) eine signifikante antikanzerogene Aktivität gegen Lungenzellen (A549), aber eine geringe Wirkung gegen kolorektale Adenokarzinomzellen (Caco-2).

Schlüsselwörter Physalis peruviana · Phenole · Flavonoide · DPPH · Antikanzerogene Aktivität

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Introduction

The golden berry (*Physalis peruviana* L.) is an exotic fruit that belongs to the Solanaceae family. The fruit is originated in South America and today it is grown commercially in several tropical and subtropical countries (Novoa et al. 2006; Al-Olayan et al. 2014). A golden berry is an annual plant that grows all over the world. *Physalis peruviana* L. is known as golden berry in English speaking countries, uchuva in Colombia, cape gooseberry in South Africa, uvilla in Ecuador, ras bhari in India, aguaymanto in Peru, topotopo in Venezuela—some of the multiple names for this fruit around the world (Erkaya et al. 2012). World's golden berry fruit cultivation area is nearly 30,622 ha and 162,386 t of yield is obtained from this area (FAOSTAT 2013). *Physalis peruviana* is an herbaceous, semi-shrub, that is upright, perennial in subtropical zones, and can grow until it reaches 0.9 m. The fruit with an approximate weight of 4–5 g is protected by an accrescent calyx and covered by a brilliant yellow peel (Mayorga et al. 2001).

The golden berries are popular fruits known for their organoleptic properties (flavor, odor and colour), nutritional value (vitamins A, B and C) and health benefits (Puente et al. 2011). Although golden berries are generally commercialized as fresh products, the fruits are also used in sauces, syrups, and marmalades (Puente et al. 2011), or dehydrated (similar to grape raisins) for use in bakeries, cocktails, snacks, and cereal breakfast. *Physalis peruviana* contains health-promoting compounds such as vitamin C (Bravo et al. 2015; Olivares-Tenorio et al. 2016), carotenoids (Fischer et al. 2000), flavonoids (Licodiedoff et al. 2013b) and have antioxidant activity (Bravo et al. 2015; Licodiedoff et al. 2013a).

Many medicinal properties are attributed to *Physalis peruviana* L. such as antispasmodic, diuretic, antiseptic, sedative, analgesic, helping to fortify the optic nerve, throat trouble relief, elimination of intestinal parasites and amoeba. There have also been reported antidiabetic properties, recommending the consumption of five fruits a day. So far, there are no studies that indicate possible adverse effects (Rodríguez and Rodríguez 2007). The medicinal properties are to purify blood of kidneys, decrease albumin, clean the cataract, to calcify and control amebiasis (Corporación et al. 1994). There are studies indicating that eating the fruit of *P. peruviana* L. reduces blood glucose after 90 min postprandial in young adults, causing a greater hypoglycemic effect after this period (Rodríguez and Rodríguez 2007).

The aim of this work is to study the chemical composition of *Physalis peruviana* fruits and its antioxidant, antimicrobial and anticancer activity.

Materials and Methods

Plant Materials

The fruits of *Physalis peruviana* L. were collected from local market in Egypt.

Microbial Strain

Table 1 illustrates the microorganisms used in this study. They were obtained from the American Type Culture Collection (ATCC) as well as the culture collection of the Microbiology Lab, Cairo University Research Park (CURP), Faculty of Agriculture, Cairo University.

Extraction Method

The fruits were cleaned and washed thoroughly under tap water, and then the roots were freeze-dried and grinded into fine powder using an electric blender. The powder was dried in an oven at 40 °C for 24 h. The fine powder sample (500 mg) was extracted in 10 ml ethanol or distilled H_2O for 24 h using a shaker, then the extract was filtered and the samples were stored at 4 °C until use (Sumathy and Sumathy 2011). All analysis was done in the labs of Cairo University, Research Park (CURP), Faculty of Agriculture, Cairo University, Cairo, Egypt.

Total Polyphenol Content

The total phenolic content was estimated by Folin Ciocalteu method as described by Singleton and Rossi (1965). The absorbance was measured at 765 nm using a spectrophotometer Thermo Scientific HERYIOS.

Table 1 Microbial strains used to test the antimicrobial activities of *Physalis peruviana* fruit

Microbial group	Indicator strain	Positive control	Cultivation conditions
Gram-positive bacteria	Staphylococcus aureus (ATCC 25923)	Kanamycin	Muller-Hinton broth, 37 °C/24 h
	Bacillus cereus (ATCC 33018)		Muller-Hinton broth, 30 °C/24 h
Gram-negative bacteria	Escherichia coli (ATCC 8739)	Polymyxin	Muller-Hinton broth, 37 °C/24 h
	Salmonella typhimureum (ATCC 14028)		Muller-Hinton broth, 37 °C/24 h
Fungus	Aspergillus niger (nrrl 326)	Nystatin	Sabouraud dextrose broth, 25 °C/3 days
	Candida albicans ATCC 10231		Sabouraud dextrose broth, 25 °C/24 h

Total Flavonoid Content

The flavonoids content was determined by aluminium trichloride method as described by Zhishen et al. (1999). The absorbance was measured at 510 nm using a spectrophotometer.

Total Tannin Content

Tannin content in *Physalis peruviana* fruits was determined by using Folin-Denis reagent as described by Saxena et al. (2013). The absorbance was read at 700 nm using spectrophotometer.

Total Alkaloid Content

Alkaloid content was measured according to the method described by Adham (2015).

The percentage of total alkaloid was calculated as:

$$\text{Percentage of total alkaloid} = [\text{Weight of residue} / \text{Weight of sample}] \times 100$$

Total Anthocyanine Content

Fresh weight of *Physalis peruviana* fruit was homogenized in methanol containing 1% (v/v) HCl and then filtrated. The filtration was read at 530 and 657 nm using spectrophotometer as described by Mancinelli et al. (1976).

Total Carotenoid Content

Total carotenoids of *Physalis peruviana* fruits were extracted using a mixture of hexane: acetone (1:1 v/v) as described by Jeyanthi et al. (2014). The absorbance of carotenoid was read at 630 nm using spectrophotometer.

Water Soluble Vitamins

Sample Preparation

Water soluble vitamins were determined by HPLC analysis after extraction from the sample according to Albala-Hurtado et al. (1997). Dry weighed 0.2 g of *Physalis peruviana* fruit powder was placed into centrifuge tube and 15 mL of deionized water were added. After 15 min of ultrasonic extraction, the tubes were centrifuged at 4000 rpm for 5 min, then quantitively transferred to 25 mL volumetric flask, and water was added to the mark. The extract was filtered through 0.2 µm nylon membrane before injection.

Instrument Conditions

Agilent 1260 infinity HPLC Series (Agilent, USA), equipped with Quaternary pump, a Kinetex XB-C18 column 100 mm
× 4.6 mm (Phenomenex, USA), operated at 35 °C. The separation was achieved using a binary linear elution gradient with (A) 25 mM NaH_2PO_4 pH = 2.5 and (B) methanol. The injected volume was 20 µL. Detection: VWD detector set at 254 nm for ascorbic acids and 220 nm for vitamins B3, B6, B9 and B12.

Extraction of Phenolic and Flavonoid Compounds

0.2 g dry sample were extracted with 20 ml ethanol 80%, soaked in brawn bottle for 24 h at room temperature, centrifuged for 5 min, volume adjusted to 25 ml by ethanol 80%, filtered through Whatman filter paper, 10 ml of the solution evaporated to dryness then dissolved in 5 ml HPLC grade methanol 50%, filtered through PTFE filter with pore size 0.2 µm.

Instrument Conditions for Phenolic Compounds

Agilent 1260 infinity HPLC Series (Agilent, USA), equipped with Quaternary pump, a Zorbax Eclipse plusC18 column 100 mm × 4.6 mm i. d., (Agilent technologies, USA), operated at 30 °C. The separation was achieved using a ternary linear elution gradient with (A) HPLC grade water 0.2% H_3PO_4 (v/v), (B) methanol and (C) acetonitrile. The injected volume was 20 µL. Detection: VWD detector set at 284 nm.

Instrument Conditions for Flavonoids

HPLC, Smart line, Knauer, Germany., equipped with binary pump, a Zorbax Eclipse plusC18 column 150 mm × 4.6 mm i. d., (Agilent technologies, USA), operated at 35 °C. Eluent: methanol: H_2O with 0.5% H_3PO_4, 50:50 with flow rate 0.7 ml/min, The injected volume was 20 µL. Detection: UV detector set at 273 nm and data integration by ClarityChrom® software. This method was the modification of methods by Goupy et al. (1999) and Mattila et al. (2000) for fractionating the polyphenols and flavonoids, respectively.

DPPH Free Radical Scavenging Activity (RSA)

The antioxidant activity of *Physalis peruviana* fruit extract was measured in terms of hydrogen donating or radical scavenging ability using the stable DPPH method as modified by Park et al. (2006). The reaction mixture containing 1 ml of the extract at different concentrations (40, 80,

120, 150 µg/ml) and 1 ml of DPPH (0.2 mM) was vigorously shaken and incubated in darkness at room temperature for 30 min. The absorbance was read at 517 nm using UV visible spectrophotometer. Radical scavenging activity was expressed as percent of inhibition and was calculated using the following formula:

$$\% \text{ DPPH} = [\text{Absorbance of Control} - \text{Absorbance of Sample}/\text{Absorbance of Control}] \times 100$$

Antibacterial Activity

Agar disc diffusion method was used to evaluate antibacterial activity of *Physalis peruviana* fruits as described by Bauer et al. (1966). The strains were grown on Mueller-Hinton agar slants at 37 °C for 24 h and checked for purity. After the incubation, the cells were washed off the surface of agar and suspended in sterile physiological solution. The number of cells in 1 ml of suspension for inoculation measured by McFarland nefelometer was 5 × 107 CFU/ml. 1 ml of these suspensions was homogenized with 9 ml of melted (45 °C) Mueller-Hinton agar and poured into Petri dishes. On the surface of the agar, 5 mm diameter paper discs (HiMedia®, Mumbai, India) were applied and impregnated with 15 µl of samples. The plates were incubated at the optimum temperature for each indicator strain (Table 1) and tested after 24, 48 and 72 h. Growth inhibition was scored positive in the presence of a detectable clear zone (ZI) around the disc and expressed in mm. Experiments were carried out in triplicates and the inhibition zone was recorded as the average of the replicates ± SD.

In Vitro Cytotoxicity Assay

Human lung cancer (A549) and colorectal adenocarcinoma Caco-2 cells were purchased from CURP, faculty of Agriculture at Cairo University (Egypt). Cells were maintained in (DMEM) supplemented with 10% heat inactivated fetal bovine serum, 100 µg/ml streptomycin and 100 unit/ml penicillin g potassium, in a humidified 90% and 5% (V/V) CO_2 atmosphere at 37 °C. The cytotoxicity of ethanolic extracts was tested by the neutral red (NR) assay as previously described by Repetto et al. (2008). Exponentially growing cells were collected using 0.25% Trypsin-EDTA and seeded in 96-well plates at 20,000 cells/well. After incubation (overnight), extracts were added in various concentrations (10, 50, 100, 200, 400, and 800 µg/ml); 4 wells for each concentration. After treatment with extracts for 24 h, media were removed and cells were exposed to neutral red solution for 4 h at 37 °C. Destin solution was used to dissolve the NR stained cells and color intensity was measured at 540 nm microplate reader (Biotek, ELX808).

Statistical Analysis

All results were expressed as mean values ± standard deviation. Comparisons were performed by analysis of variance (ANOVA). Statistical analyses were run using SAS software.

Results and Discussion

Chemical Constituents of *Physalis peruviana* Fruit

Data in Table 2 shows that the ethanolic extract of *Physalis peruviana* fruit contains phenols (125.4 mg/g DW), flavonoids (6.39 mg/g DW), tannins (14.8 mg/g DW), alkaloids (3.37 g/100 g DW), anthocyanins (6.68 µg/100 g FW) and carotenoids (1.53 mg/100 g FW). These results are similar to Yıldız et al. (2015) who found that the antioxidant capacity and total phenolic content in fruit of *Physalis peruviana* were 57.67% and 145.22 mg GAE/100 g, respectively. The fruits of *Physalis peruviana* have high nutritional value because of their high contents of vitamins, minerals and antioxidants. These plants have also potential medicinal properties like antibacterial, antiinflammatory, and antioxidant properties (Dimayuga et al. 1998; Yen et al. 2010). The presence of the secondary metabolites in *Physalis peruviana* has contributed to its medicinal value as well as physiological activity (Sofowara 1993). Carotenoids are responsible for the orange colour in the fruit of *P. peruviana* L. (Ramadan and Morsel 2003). β-carotene is very important in the prevention of certain human diseases such as cancer. The reason that carotenoids prevent cancer is related to the antioxidant activity that deactivates free radicals generated in tissues (Castro et al. 2008).

Phytochemical components are responsible for both pharmacological and toxic activities in plants. They are

Table 2 Quantitative phytochemical analysis of *Physalis peruviana* fruit

Constituents	Values in ethanolic extract
Total phenols (mg Gallic acid/g DW)	125.44 ± 0.29
Total flavonoids (mg Quercetin/g DW)	6.39 ± 0.47
Total tannins (mg Tannic acid/g DW)	14.82 ± 0.62
Total alkaloids (g/100 g DW)	3.365 ± 0.006
Total anthocyanins (µg/100 g FW)	6.675 ± 0.18
Carotenoids (mg/100 g FW)	1.53 ± 0.06

Values are mean ± SD of three replicate analyses.

used for therapeutic purposes to cure various diseases and to heal injuries (Okwu and Josiah 2006; Abdel-Rahim and El-Beltagi 2010). For instance, flavonoids have been shown to have antibacterial, antiinflammatory, antiallergic, antiviral, antineoplastic and antioxidant effects; they act as free radical scavenger and metal chelators (Mishra et al. 2009). Alkaloids contribute to plant species fitness of survival, have pharmacological effects and are used as medication and recreational drugs (Roger and Wink 1998; Kobeasy et al. 2011). They protect plants against infection with insects by the production of the bitter taste that repels insects from feeding on plant leaves. Tannins may provide protection against microbial degradation of dietary proteins in the rumen (Aletor 1993; Afify et al. 2011). In addition, carotenoids have protective effects against several diseases such as cancer, coronary heart disease, inflammation reactions, and age-related macular degeneration and act as an antioxidants (Eisenhauer et al. 2017; Sözgen et al. 2013).

HPLC of Soluble Vitamins

Vitamins are organic substances present in very small quantities in food, but necessary for metabolism. They are grouped together not because they are chemically related or have similar physiological functions, but because they are vital factors in the diet and they all were discovered in connection with the diseases that cause its lack (Latham 2002).

The ethanolic extract of *Physalis peruviana* fruit contains vitamin C (42.5 mg/100 g DW), vitamin B3 (3.84 mg/100 g DW) and vitamin B6 (4.59 mg/100 g DW) (Table 3). These results are similar to Puente et al. (2011) who found that the fruit of *P. peruviana* L. is highly nutritious, having high levels of vitamins A, B and C. Also, Hassanien (2011) reported that gooseberry is a good source of provitamin A, minerals, vitamin C, and vitamin B complexes. The data in Table 3 show a high level of ascorbic acid (vitamin C) in the fruit of *P. peruviana* L. This vitamin plays an important role in human nutrition, including growth and maintenance of tissues, the production of neurotransmitters, hormones and immune system responses. Vitamin C is an important dietary antioxidant, since it reduces the adverse effects of reactive oxygen and reactive nitrogen. The latter can cause damage to macromolecules such as lipids, DNA and proteins, which are related to cardiovascular disease, cancer and neurodegenerative diseases (Naidu 2003).

Table 3 Water soluble vitamin contents (mg/100 g DW) of *Physalis peruviana* fruit

Vitamin contents	Values
Vitamin C (Ascorbic acid)	42.52 ± 0.34
Vitamin B3 (Niacin)	3.84 ± 0.12
Vitamin B6 (Pyridoxine)	4.59 ± 0.15

Values are mean ± SD of three replicate analyses.

HPLC of Phenolic Compounds

The data in Table 4 show that the ethanolic extract of *Physalis peruviana* fruit contains a number of phenolic compounds such as gallic acid (183.0 mg/100 g DW), catechol (23.7 mg/100 g DW), p-Hydroxy benzoic acid (38.6 mg/100 g DW), caffeine (9.3 mg/100 g DW), vanillic acid (10.5 mg/100 g DW), syringic acid (9.2 mg/100 g DW), vanillin (2.5 mg/100 g DW), benzoic acid (28.8 mg/100 g DW), o-Coumaric acid (5.2 mg/100 g DW), salicylic acid (7.7 mg/100 g DW) and cinnamic acid (3.1 mg/100 g DW). These results are similar to Ramadan et al. (2015). Ethanol extract of *Physalis peruviana* fruit has higher total phenolics, flavonoids and antioxidant contents than does hexane extract.

Phenolic compounds, biologically active components, are the main agents that can donate hydrogen to free radicals and thus break the chain reaction of lipid oxidation at the first initiation step. This high potential of phenolic compounds to scavenge radicals may be explained by their phenolic hydroxyl groups (Oke et al. 2009). Various bioactive compounds (flavonoids and phenolics) are reported to be present in *P. peruviana* (Dinan et al. 1997). Some of these compounds have a strong antioxidant property and prevent peroxidation (Wang et al. 1999).

In addition, the ethanolic extract of *Physalis peruviana* fruit contains a number of flavonoid compounds such as neringenin (32.7 mg/100 g DW), kaempferol (8.8 mg/100 g DW) and apigenin (6.7 mg/100 g DW). Similar results were reported by Dinan et al. (1997) and Keith et al. (1992) who found different compounds such as phygrine, kaempferol

Table 4 HPLC analysis of phenolic and flavonoid compounds of *Physalis peruviana* fruit extract (mg/100 g of DW)

Phenolic compound	*Concentration*
Gallic acid	183.08
Catechol	23.70
p-Hydroxy benzoic acid	38.59
Caffeine	9.33
Vanillic acid	10.50
Syringic acid	9.18
Vanillin	2.45
Benzoic acid	28.80
o-Coumaric acid	5.24
Salicylic acid	7.74
Cinnamic acid	3.11
Flavonoid compound	*Concentration*
Neringenin	32.72
Kaempferol	8.81
Apigenin	6.70

Table 5 Antioxidant activity of *Physalis peruviana* fruit (DPPH method)

Conc. (µg/ml)	DPPH % in ethanolic extraxt
40	58.41
80	58.53
120	64.53
150	72.83
IC_{50} (µg/ml)	21.47

and quercetin in *Physalis peruviana*. Some of these compounds have strong antioxidant property and prevent peroxidative damage to liver microsomes and hepatocytes (Wang et al. 1999; Watson and Oliveira 1999). These flavonoids (quercetin derivatives and kaempferol) have been best known for their beneficial biological functions, including antioxidation, antiinflammation, and inhibition of tumor proliferation (Birt et al. 2001; Nijveldt et al. 2001; Yao et al. 2004; El-Desoky et al. 2018).

Antioxidant Activity

The effect of antioxidants on DPPH radical scavenging was thought to result from their hydrogen donating ability. DPPH is a stable free radical and accepts an electron or hydrogen radical to become a stable diamagnetic molecule. The reduction capability of DPPH radicals was determined by the decrease in its absorbance at 517 nm induced by antioxidants. It is visually noticeable as a discoloration from purple to yellow. The scavenging of DPPH radicals increased with increasing extract concentration from 40, 80, 120 and 150 µg/mL (Table 5). The IC_{50} value of ethanolic *Physalis peruviana* fruit was 21.47 µg/mL concentration. IC_{50} value indicates the concentration of the test sample required to inhibit 50% of the free radicals. The IC_{50} value is a parameter widely used to measure the free radical scavenging activity (Cuvelier et al. 1992); a smaller IC_{50} value corresponds to a higher antioxidant activity. These results are similar to Ramadan et al. (2015) who found that ethanol extract of Cape gooseberry fruit achieved higher antioxidant activity than did hexane extract, and thus tested as having anticancer activity. The antioxidant activity of *Physalis peruviana* is due to the high levels of polyphenols and high levels of vitamins A and C (Jyothibasu and Venkata 2015). Narváez-Cuenca et al. (2014) indicated that *P. peruviana* L. has a high antioxidant activity. The high antioxidant capacity of the fruits is probably due to their richness in oxygenated monoterpene compounds.

Antimicrobial Activity

The agar diffusion method was used to evaluate the antibacterial and antifungal activity of ethanolic extract of *Physalis peruviana* fruit by using selected gram-positive, gram-negative bacteria and fungus. The diameter of the inhibition zone (ZI) is shown in Table 6. The data indicate that the extract exhibited the activity against the investigated food pathogens. Gram-positive *Bacillus cereus* demonstrated higher susceptibility than gram-negative *Escherichia coli* and *Salmonella typhimureum*. The extract showed antibacterial activity against *Bacillus cereus* (ZI = 17.2 mm), one of the most common gram-positive bacterium causing food poisoning. On the other hand, a weak antimicrobial activity was found against *Staphylococcus aureus* (ZI = 8.6 mm). The extract showed positive effect on the fungus used (*Aspergillus niger* and *Candida albicans*). The extract showed higher antifungal acitivity against *Aspergillus niger* (ZI = 7.5 mm) than *Candida albicans niger* (ZI = 3.6 mm). These results are similar to Jaca and Kambizi (2011) who found that the aqueous leaf extracts of *Physalis peruviana* L. were also found to have antibacterial activity against three gram-negative bacteria (*Eschericia coli, Proteous vulgaris Seratia mersescens*) and three gram-positive bacteria (*Bacillus subtilis, Micrococcus kristinae* and *Staphylococcus aureus*). Also, Özgür et al. (2014) found that leaf and shoot extracts of *P. peruviana* showed growth inhibition effect on microorganisms tested. All extracts inhibited both gram-positive and gram-negative bacteria growth, but there was more inhibition on gram-positive strains. The disc diffusion results presented that these extracts showed antibacterial activity to *Staphylococcus aureus, Escherichia coli* and *Erwinia herbicola*.

The presence of flavonoids, phenols, tannins and alkaloids phytochemical components in *P. peruviana* L. extracts can be the reason of its use in traditional folklore medicine. Flavonoids have been found to be effective against a wide range of microbes (Cowan 1999). Their mechanism of action is thought to be caused by their ability to form complexes with extracellular and soluble protein and bacterial

Table 6 Antibacterial activities of ethanolic extract of *Physalis peruviana* fruit against selected bacterial strains

Samples	(ZI) Inhibition zone (mm)[a]					
	Gram-positive bacteria		Gram-negative bacteria		Fungus	
	S. aureus	*B. cereus*	*E. coli*	*S. typhimureum*	*A. niger*	*C. albicans*
Physalis peruviana ethanolic fruit extract	8.63 ± 0.18	17.15 ± 0.16	12.46 ± 0.21	9.33 ± 0.24	7.5 ± 0.25	3.6 ± 0.08

Values are mean ± SD of three replicate analyses
[a]Well size = 5 mm

Table 7 Anticancer activities of *Physalis peruviana* fruit

Concentration (µg/ml)	Lung cancer (A549) Viability %	Colorectal adenocarcinoma (Caco-2)
10	89.0	100
50	86.6	100
100	85.0	100
200	82.0	100
400	71.0	100
800	66.0	94
IC_{50} (µg/ml)	1260.9	3733

cell walls. Tannins are associated with formation of irreversible complexes with nucleophilic amino acids in proteins many times leading to inactivation of proteins, loss of function and death of microorganisms. Alkaloids have been attributed to posses microbicidal properties to protozoas such as *Giardia* and *Entamoeba* species. The mechanisms of action of the highly aromatic alkaloid such as berberine and harmane are believed to be in their ability to interact with DNA (Shakya 2016). The presence of the various phytochemical compounds present in *P. peruviana* L. could be associated with the antimicrobial activities associated with the extracts.

Anticancer Activity

The results in Table 7 show the cytotoxic activity of *Physalis peruviana* fruit as an anticancer agent (towards to lung) and the IC_{50} dose. The percentage of lung cancer cell line (A549) viability was decreased by increasing the concentrations of the methanolic extract of *Physalis peruviana* fruit (Fig. 1). On the other hand, the viabitity of colorectal adenocarcinoma Caco-2 was not affected by all concentrations of *Physalis peruviana* fruit except the high concentrations (800 µg/ml) which showed slight decrease in the viability of Caco-2 cell line (Fig. 2). Similar results were reported by Wu et al. (2004) who performed cytotoxic assays with ethanolic extracts of *P. peruviana* on the Hep G2, Hep 3B, and PLC/PRF/5 human hepatoma cell lines, the IC_{50} values were 9.43 ± 0.30, 41.25 ± 1.40, >100 µg/mL, respectively. Lan et al. (2009) showed that the ethanolic extract of *Physalis peruviana* inhibits growth and induces apoptotic death of human Hep G2 cells in culture. Also, Ramadan et al. (2015) found that Cape gooseberry fruit extract was more potent in inhibiting colon cell lines

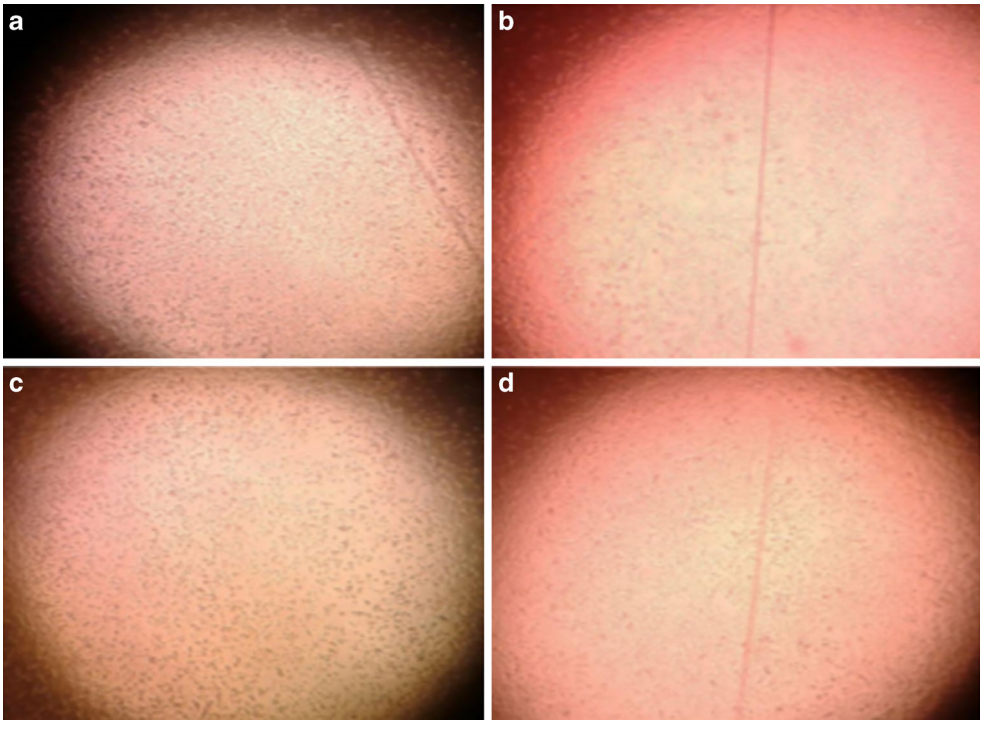

Fig. 1 Morphological observation of cancer cell lines (A549) by 40X magnification power. **a** Negative Control, **b** 800 µg/ml Thevetia Peruviana, **c** Positive control (Dox-HCI) 6 µg/ml, **d** 400 µg/ml Thevetia Peruviana

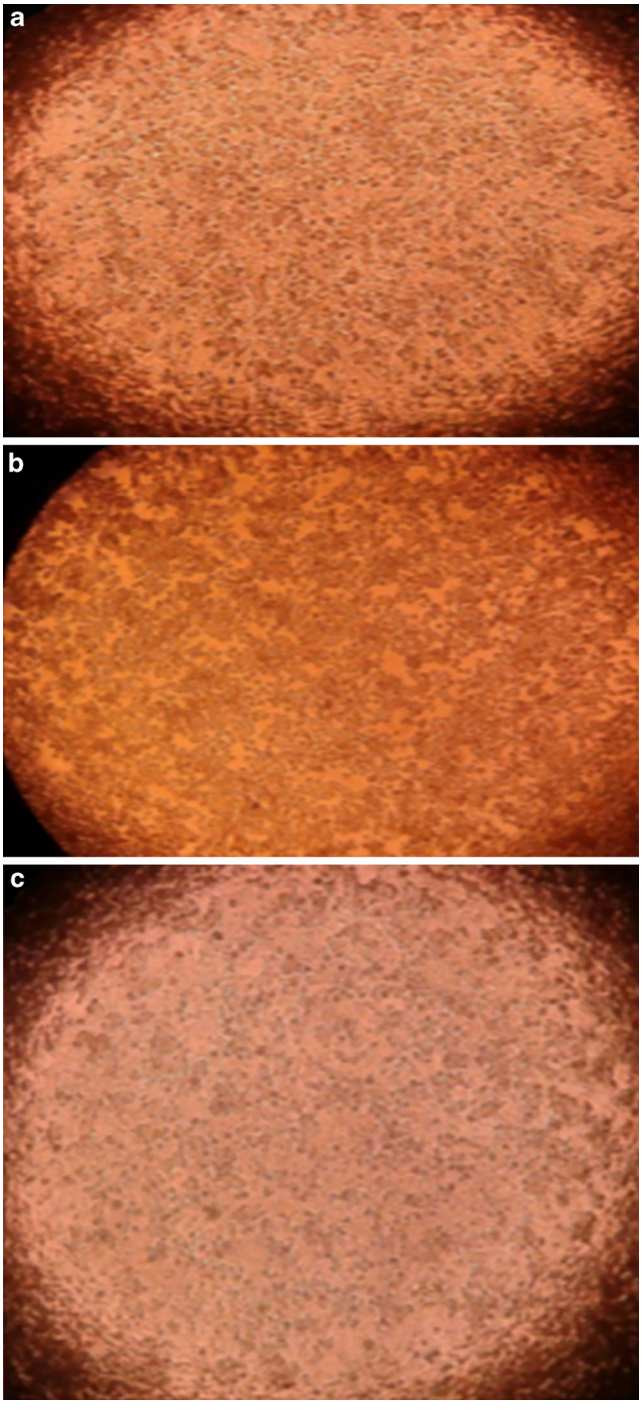

Fig. 2 Morphological observation of colorectal adenocarcinoma Caco-2 by 40X magnification power. **a** Negative Control, **b** Positive control (Dox-HCI) 6 µg/ml, **c** 800 µg/ml Thevetia Peruviana

(IC50: 142 µg/ml) compared with breast cell lines (IC50: 371 µg/ml). Cancer is often associated with increased risk of death and the toxic side effects caused by the modern medicine. Many cancer patients seek alternative and complementary methods of treatment such as usage of phytomedicine. Natural dietary agents have drawn a great deal of attention because of their potential to suppress cancers and to reduce the risk of cancer development by decreasing oxidative stress, which plays a significant role in the pathogenesis and pathophysiological process of cancer (Lunawati et al. 2012). Polyphenolic compounds in *Physalis peruviana* fruit might inhibit cancer cells by xenobiotic metabolizing enzymes that alter metabolic activation of potential carcinogens, while some flavonoids could also alter hormone production and inhibit aromatase to prevent cancer cells. The mechanism of action of anticancer activity of phenols could be by disturbing the cellular division during mitosis at the telophase stage. It was also reported that phenols reduce the amount of cellular protein and mitotic index and colony formation during cell proliferation of cancer cells (Anand et al. 2013).

Conclusion

Egyptian *Physalis peruviana* fruits may be suggested as a potential source of natural antioxidant and anticancer agents. This will be important as an indication of the potentially nutraceutical and economical utility of *Physalis peruviana* as a new source of bioactive phytochemicals and functional food. *Physalis peruviana* fruit preparations can be used as a cheaper alternative to the conventional disinfectants. *Physalis peruviana* fruit is a source of a good variety of compounds (phenols, flavonoid, vitamins and carotenoids).

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Conflict of interest H. S. El-Beltagi, H. I. Mohamed, G. Safwat, M. Gamal and B. M. H. Megahed declare that they have no competing interests.

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