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EFFICIENT UTILIZATION OF WATERMELON WASTES

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Abstract

The watermelon is a fruit used on a large scale in human nutrition. Cucurbitceae species are a source of many nutrients such as protein,minerals, lipids as well as ingredients for medicine. The main non-edible parts are the seeds and the rind that make them agro-wastes. Watermelon seeds and rind may represent an appropiate tool for the treatment of various diseases in those countries that use a more classical therapeutic approach. In this article is made a brief analysis of the ways to recover the resulted wastes from the cultivation of watermelon. The most promising directions are obtaining the bioactive compounds, biofertilizers and biogas.

Key words: *watermelon, Citrullus lanatus, wastes.*

INTRODUCTION

Watermelon (*Citrullus lanatus* L.) is a fruit crop part of the Cucurbitaceae family, along with the cucumber, zucchini and melon. It grows in temperate regions of Africa, Turkey, China, Egypt, Iran, Mexico, South Korea, India and some parts of the United States. The fruit of the *Citrullus lanatus* L. is usually used as food and in the pharmaceutical industry for the nutritional factors of the fruit and as well as seeds.

Present review is a collection of information about the phytochemistry, pharmacology and utilization of the watermelon wastes.

BOTANICAL CLASSIFICATION

Kingdom: Plantae
Division: Magnoliophyta
Order: Cucurbitales
Family: Cucurbitaceae
Genus: Citrullus
Species: lanatus

BIOLOGY

Citrullus lanatus known as watermelon, is an annual herbaceous vine with up to 10 m stems creeping or liying on the ground. Leaves are 3-20 cm, deeply palmately lobed with 3 to 5 lobes. Leaf stalks are between 2 and 19 cm long. Male flowers on 1.2-4.5 cm long pedicels. Flowers 1-2.5 cm long and coloured in pale green. Flowers are monoecious, solitary, on pedicels long up to 4.5, with pale green united petals. Fruit of wild plants are nearly spherical, in diameter 1.5- 20 cm, green combined with darker green. The fruit of the cultivated plants are up to 20x60 cm, weight between 3 and 5 kg, the form ellipsoidal or spherical, colour is green or yellowish, or variously mottled or striped. The fruits vary in colour, taste and odour (Dane F., 2007).

Seeds are numerous, 6-10 mm long, compressed, pyriform, black or dark brown. They continue to mature as the fruit rind lightens in colour.

Botanical name: *Citrullus lanatus*

PRODUCTION TECHNOLOGY

Watermelon is cultivated in all over the world in the warmer parts, but is trully native from the Tropical Africa where are sandy and dry areas.

As climate *Citrullus lanatus* needs a dry and warm climate and to develop and grow successfully must be cultivated at a 30-35°C temperature. The flowering as the fruit development are helped by high light intensity and temperature. The areas with high humidity during the fruit formation stage and more rain at maturity are not going to thrive.

It is compatible with all types of soil but most suitable are the sandy soils with a pH range from 5.5-7.5. The soil must be drained.

COMPOSITION

Table 1. Seed nutritonal values (per 100g)

COMPONENT	VALUE	AUTHOR
Protein	34.1 g	Gopalan C., 1971
	35.66 g	Tarek A. El-Adawy, 2001
	35%	Okunrobo O., 2012
Fat	52.6g	Gopalan C., 1971
	50.10g	Tarek A. El-Adawy, 2001
	50%	Okunrobo O., 2012
Arginine	900 mg/g of N	Gopalan C., 1971
	1161.25 mg/g	Tarek A. El-Adawy, 2001
Calcium	100 mg	Gopalan C., 1971
	150 mg	Tarek A. El-Adawy, 2001
	16.8 mg	Okunrobo O., 2012
Phosphorus	937 mg	Gopalan C., 1971
	1279 mg	Tarek A. El-Adawy, 2001
Zinc	10.6 mg	Tarek A. El-Adawy, 2001
	1.2 mg	Okunrobo O., 2012
Magnesium	11.4 mg	Okunrobo O., 2012
Fiber	5%	Okunrobo O., 2012
Potasium	7.8 mg	Okunrobo O., 2012
Sodium	5.7 mg	Okunrobo O., 2012

Chemical components

The watermelon seeds are free from glucoside and alkaloids. The resin has cucurbitol ($C_{24}H_{40}O_4$) and a small amount of phytosterol. The shell of the seed it's 48.7% of the entire seed weight. Another fatty acid present but in small amount and in the shell is the arachidic acid (Biswas R. et al., 2016).

Anti-nutritional factors from watermelon seed

Citrullus vulgaris has a source of protein inhibitors from the watermelon seeds are the amino acid sequences of two trypsin inhibitors that contain Arg5-Ile6 bond at their reactive site.

In the seed kernel flour of *Citrullus lanatus* phytic acid and trypsin inhibitor were found in considerable amount (Biswas R. et al., 2016).

Antioxidants – Polyphenols and flavonid content

The methanolic extract from seeds of *Citrullus vulgaris* have a high antioxidants activity and a high content of flavonoids and polyphenols.

The n-hexane extract of *Citrullus lanatus* seeds showed the highest antioxidant activity and total phenolic content where the ethanol extract had highest total flavonoid content.

Antioxidant activity of *Citrullus lanatus* of chloroform, ethyl acetate and methanol, mesured by DPPH method. Methanolic extract of *Citrullus lanatus* seed showed maximum antioxidant potential (Naresh Singh Gill, 2011).

PHARMACOLOGY

Laxative activity of aqueous fruit pulp extract at doses depending on the body weight (250, 500, 1000 mg/kg), was based on the weight of the faeces matter. The laxative activity was seen after administered orally and on treatments with loperamide to induce constipation. Another thing is that happened is a significant increase of the intestinal transit (in comparison with castor oil (Swapnil Sharma, 2011).

Antimicrobial activity of chloroformic, hexane and ethanolic extracts of leaves, stem, fruits and seeds against bacteria (*E. coli, Staphylococcus aureus, Pseudomonas aeruginosa, Bacillus subtilis and Proteus vulgaris*) and fungi (*Aspergillus niger, Candida albicans*). The activity was tested by cup-plate diffusion methods and disc diffusion method. The highest antimicrobial results was in using the chloroform extract of the fruit and it showed results against *Bacillus subtilis* (38 mm), *Escherichia coli* (37 mm), *Staphylococcus aureus* (36 mm), *Proteus vulgaris* (23 mm) and *Pseudomonas aeruginosa* (19 mm). The highest antifungal activity was shown using ethanolic extract of the fruit pulp and stem on *Candida albicans* (41 mm). *Aspergillus niger* on the chloroform extract of the seed was very sensitive and also on the ethanolic extract of the leaves (37 mm), in comparison with drugs as clotrimazol and gentamicin (Loiy Elsir Ahmed Hassan, 2011).

Cucurbitacin L 2-O- -glucoside pure and Cucurbitacin E isolated from *Citrullus lanatus* var. *citroides* have a strong antigiardial activity against *Giardia lamila in vitro* (IC = 2 and 5 µg/ml after 5 days). The best of all examinated extract was the ethyl acetate extract and then petroleum ether followed by butanol with IC50 0.1, 0.2 and 0.5 µg/ml) (Loiy Elsir Ahmed Hassan, 2011).

Anti ulcer activity of *Citrullus lanatus* seeds of methanolic extract was tested by pyloric ligated and water immersion stress induced ulcer models on rats. The rats trated with methanolic extract in 300 mg/kg have shown a significant decrease in the gastric volume, free acidity and total acidity for the pyloric ligated ones and an inhibition of ulcer by decrease in ulcertive index (Altas S. et al., 2011; Biswas R. Et al., 2016).

Anti-inflammatory activity of *Citrullus lanatus* seed oil *in vivo* and *in vitro* evaluation

In vitro anti-inflamatory activity was screened for human red blood cell membrane stabilization method and *in vivo* by carrageenan-induced paw edema in rat model. The oil had a significant reduction of the edema maximum at 3 hours (the percentage in the reduction of the paw volume 44.44%, 44.56% and 63.11% with 50 mg/kg, 100 mg/kg of *Citrullus lanatus* seed oil and 10 mg/kg with diclofenac. (Madhavi P. et al., 2012)

Anti-hyperlipidemic on hypercholesterolemia induced atherosclerosis in mice

Mice that consumed *Citrulls lanatus* extract had very increased plasma citrulline concentrations, lower body weight and fat mass, a significant decrease plasma cholesterol concentration by the reduction of lipoprotein cholesterol. The consumption of the extract resulted in reduction of atherosclerosis in aortic arch and thoracic regions (Poduri A. et al., 2012).

***In vivo* activity of watermelon seeds**

Effect on growth

Watermelon seed full-fat and watermelon seed meal samples were analyzed for composition and introduced in the diet of broiler chicks. The full fat increased the weight gaining ($P<0.05$), the protein consumption and feed intake. The feed intake was increased linearly with increasing levels of watermelon seed meal. This shows that watermelon seed full-fat can be used as food ingredients in the diets of broiler chicks at up to 20%. Male albino rats fed with *Citrullus lanatus* seeds had higher weight gain ($P<0.01$) and protein efficiency ratio than the group of rats fed with stock diet.

Anti-diabetic effect

Citrullus colocynthis seeds aqueous extracts in streptozotocin induced in diabetic rats had a anti hyperglycemic effect, glucose homeostasis and body weight maintenance.

Cardioprotective effect

A group of male albino rats fed with *Citrullus vulgaris* had the level of serum triglyceride and VLDL-C significantly decreased ($P<0.05$). Serum total cholesterol, LDL and atherogenic index decreased where HDL was increased.

Anti-obesity and anti-arthritic effect

At the highest dose level of 2000 mg/kg with alcoholic and aqueous extract of *Citrullus vulgaris* seed no mortality or abnormal behavior happened at mice. The seed extracts with 200 mg/kg and 4000 mg/kg had a significant result with body weight lose, reducing the food intake, reducing serum glucose, trygliceride, cholesterol levels with an increased HDL levels in CD and AD induced obese rats (Biswas R., 2016).

VALORIFICATION OF WATERMELON WASTES

Yeast cultivation

Using the water extracts from watermelon, cabbage, a mix of residual biomass of tropical fruits and green salads can be used as substrate for yeast cultivation. Vegetables and fruit processing wastes cantain organic acids and soluble sugars, that can be used by some microorganisms, most by yeast, to produce a high contented protein biomass with no need to add any nutrients. Is possible to increase the economic value and nutrients of yeast by adding aprox. 5 µg/ml of selenium (Stabnikova O., 2005).

Carbon source for carotene production

A main carbon source for carotene production can be made using solid agro-food wastes such as watermelon rind, cabbage and peach peels and a heterothallic fungus, *Blakeslea trispora*. This fungus was able to use different origin agro-food waste, almost equivalently, for carotenoids production with a yield of over 76% in all examinated cases (Papaioannou E.H. et al., 2012).

Cutin source

A new alternative cutin source can be found in agro industrial wastes as inducers of cutinase production by *Fusarium oxysporum*. The cutin that is isolated from watermelon peels can yield 6.77 U/ml and the cutinase using apple cutin 9.64 U/ml. The Fourier transform infrared spectroscopy and C cross polarization-magic angle spinning nuclear magnetic resonance spectra solid state NMR studies show the nature of watermelon to be an aliphatic polyester of polyhydroxy fatty acids. During submerged fermentation the ester linkages in watermelon were completely hydrolyzed.

The GC-MS indicate the critical structural feature of the hydroxyl groups at ɯ-position and middle of the fatty acid chain. X-ray diffraction of the watermelon show thats it has amorphous nature. Differential scanning calorimetry indicates two endothermic transition peaks, one of the broads appear at 30-60°C and the other one at 145°C. Thermogravimetric analysis of watermelon shows that it can be thermally stable up to 200°C. Use of watermelon peels as a cutin source in the production of cutinase can receive commercial value and the industries of processing the watermelons can financially boost (Sandeep A. et al., 2015).

Producing biofertilizer

In farming situation the agro-wastes is often useless and will be discarded. The accumulation may cause environmental, health, esthetic and safety concern and that is why it requires safe disposal.

Produceing a biofertilizer using agro-wastes represents a simple and cost-effective method. Using wastes from watermelon, papaya, pineapple, banana and citrus orange and solid-state fermentation method it can produce biofertilizer and then apply on vegetable plantation. The watermelon biofertilizer had the biggest pH level (5.15) compared to the banana one that was 4.52, papaya 4.45, pineapple 4.42 and citrus the lowest, 4.08. The potassium content was the biggest at the banana fertilizer with 3.932 g K/l, followed by pineapple with 2.828, papaya 2.245, watermelon 1.529 and the least citrus orange 0.472.

The efficiency of the biofertilizer is reflected by crop growth rate. After applying on the first batch biofertilizers on the Mustard plant, *Brassica juncea* var. *rugosa*, the average weight showed that the biofertilizer had the biggest impact of growth from the watermelon one with a value of 0.100 g and the lowest from the citrus orange with 0.026 g. The second batch the best weight was still from the watermelon fertilizer with 0.208 g, the papaya 0.103 g, banana 0.072 g, citrus orange 0.059 g and the least weight 0.051 g. The untreated plant had 0.027 g. This shows shows that the acidity content in the biofertilizer affects the growth of the plant.

The average lenght of longest root in the Mustard plant sample with watermelon biofertilizer was 40.6 mm after the first batch and the second batch 70.8 mm, papaya with 31.8 mm and 47.7 mm, pineapple 28.0 mm and 37.4 mm, banana 31.6 mm and 25.8 mm and citrus orange 19.8 mm and 13.6 mm. The untreated plant had 20.1 mm.

The untreated mustard plant had the average number of leaves 3.5. The watermelon fertilizer grew 5.2 leaves and 5.6, papaya 3.8 and 5.1, banana 4.2 and 3.4, pineapple 3.6 and 2.7, citrus orange 3.6 and 2.5.

This shows that agro-wastes biofertilizers from watermelon, papaya and banana are suitable to be used as biofertilizers using solid-state fermentation (Soh-Fong Lim, Sylvester Usan Matu, 2015).

Biogas generation

Nowadays energy represents a very important factor and an inadequat energy energy supply can affect socio-economic activities and limit economic growth. Because of the rising prices of the crude oil and the degradation of the environment we have to find alternative energy sources that are renewable. Some of these sources are represented by biofuels like biogas, biodisel and bioethanol because they are feasible energy source, compatible with current combustion engine technology and distribution networks that already exist.

Watermelon rind and pineapple peels were each co-digested with food wastes in ratio 1: 1 while using rumen contents of cattle as inoculum. The generated gas had 68% Methan, 20% Carbon dioxide, 6% Nitrogen, 2.5% Hydrogen, 1.5% Hydrogen sulfide and 1% Oxygen. In terms of pathogen treatment the anaerobic digestion is found efficient, and five logarithmic units were reached with the reduction of coliforms. The establishment of using these substrates for biogas plants will reduce solid wastes and ensure a low-carbon and safe environment (Dahunsi S.O. et al., 2015).

Biosorbent for removal of trivalent chromium from aqueous solution

One of the most toxic heavy metal ions is Chromium that has adverse effects on humans and aquatic life. There are many conventional treatment processes like precipitation, ion exchange, filtration, membrane filtration, electrochemical treatment and reverse osmosis, but they have disadvantages like less efficiency, high treatment and disposal costs. Adsorption is cost effective and more efficient technique for the removal of heavy metals from wastewater.

The watermelon rind was evaluated as economical sorbent for the removal of Cr^{3+} from aqueous solution. By using varying pH, contact time, adsorbent dose and initial metal ion concetration was performed a batch mode adsorbtion. Watermelon rind maximum loading capacity was 172.6mg g^{-1} for Cr^{3+} ions at pH 3. The removal is found as rapid and the equilibrum was reached in aprox. 30 minutes and follows pseudosecond order kinetic model. Desorption studies show that watermelon rind could be used without any decrease in efficiency (Nimmala Anvesh Reddy et al., 2014).

Sorbent for removal of nickel and cobalt from aqueous solution

The most used sorbent for metal removal from effluents is activated carbon, but its application is limited due to high costs for activation and incomplete regeneration and thats why agricultural waste and industrial by-products may be low-cost effective and have better sorbents.

In process effluents we find Ni^{2+} and Co^{2+} ions from battery manufacturing, electro-planting and mineral processing and for because is toxic to humans and animal life we have to remove them. The watermelon rind is rich in polymers like citrulline, proteins, cellulose and carotenoids with functional groups such as amine (proteins), hydroxyl (cellulose) and carboxylic (pectin) and can easily bind metal ions. The maximum sorption capacity of watermelon rind was found to be 35.3 and 23.3 mg g^{-1} for Ni^{2+} and Co^{2+} ions, respectively. Ni^{2+} ions showed higher affinity and adsorption rate compared with Co^{2+} ions under the experimental conditions. Extraction of Ni^{2+} and Co^{2+} ions was significantly affected by the presence of other metals due to competition (Lakshmipathy R. et al., 2013).

Biosorbent for adsorption of methylene blue

Various industries release effluents containing dyes and cause negative impact for the aquatic organisms and humans. These are one of the causes of eutrophication and pollution, toxic and because of their aromatic complex structure and syntethic nature and potetially carcinogenic due. Most of the widely used basic dye for cotton, silk and wool is represented by methylene blue. Is known to cause dysfunction of the liver, central nervous and reproductive system, brain and kidney.

The most effective technique for the removal of methylene blue is adsorption because of its simplicity, flexibility and without generating hazardous secondary products.

Physicochemical characterization of the watermelon rind show that the carboxyl and hydroxyl groups have an important role in the adsorption of methylene blue.

The adsorption capacity of the watermelon rind for the methylene blue was 188.68 mg/g at 303K. The best dossage was 0.06 g and superior methylene blue adsortion capacity was in pH 5 solution. Acording to the thermodynamic adsorption parameters, watermelon rinds was exotheric and spontaneous (Ali H. et al., 2018).

Adsorbent for zinc removal

Waste water from mosaic industry has zinc in concentration range of 350 mg/l to 450 mg/l. Biosorption had some advantages over conventional treatment methods wich are high efficiency, low cost, minimization of chemical and biological sludge, regeneration of biosorbent and the possibility of metal recovery. Biosorbents from fruit rinds consists in citrulline, pectin, proteins, cellulose and carotenoids that have groups of hydroxyl, amine and corboxylic. These can easily bind to metal ionsby changing their hydrogen ions for metal ions or giving an electron pair coplexes with the metal ions.

The silica from the structure o the watermelon rind can enhance the biosorption process.

The optimum pH was 8, biosorbent amount 1.5 g, zinc concentration 400 mg/l and contact time was 30 minutes (Othman N. et al., 2014).

CONCLUSIONS

There are lots of parts of the watermelon that are not consumed by the human because they are considered not edible. The seeds are a source of nutrients such as minerals, proteins and lipids that are used in medicine. The watermelon seeds have low molecular weight polypeptides like albumin, globulin, glutein and lots of glutamic acid, aspartic acid and serine. Because they are rich in protein they could be used in food formulations as ingredients. They have a good impact on the human health as anti-diabetic effect, cardioprotective, anti- ulcerogenic and anti-obesity. In most of the countries there are lots of products that have incorporated watermelon seed oil although is not considered an oil seed.

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