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A comprehensive review on watermelon seed oil – an underutilized product

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Abstract: *Watermelon seed is one of the underexplored and unutilized sources of oil containing essential fatty acids, vitamin-E, minerals and also have anti-oxidant activity and is suitable for cooking. The objective of this study is to aware people about the properties of watermelon seed oil and the potential benefits of the oil. According to most of the researchers' watermelon seed oil has positive impact on growth and it has cardioprotective, hepatoprotective and anti-diabetic effects. After thorough comprehensive toxicological investigation, animal studies, physicochemical characteristics and nutritional analysis, it is recommended that it is the demand of time to explore its commercial potential.*

Keywords: *animal studies, fatty acids, physicochemical characteristics, watermelon seed oil.*

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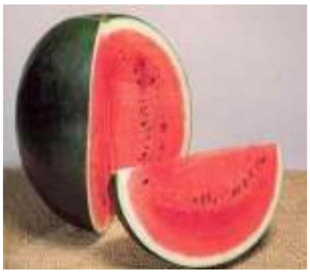
I. INTRODUCTION

Oils extracted from plant sources have a rich history of use by local people as a source of food, energy, medicine and for cosmetic applications. The continued increase in human population has resulted in the rise in the demand as well as the price of edible oils, leading to the search for alternative unconventional sources of oils, particularly in the developing countries. There are hundreds of underexplored plant seeds rich in oil suitable for edible or industrial purposes [1]. One of such underutilized product is watermelon seed oil, rich in linoleic acid (~64.5%). It is used for frying and cooking in some African and Middle Eastern American countries owning to its unique flavor [2]. Also to prevent solid waste related hazards to the environment, effort should be made to increase the utilization of these unconventional food wastes. Knowledge of the properties of the watermelon seed oil may offer insight into the nature and potential benefits of the oil.

1.1. Plant description

Watermelon, a vine-like *flowering plant*, is a member of the family of cucumber (*Cucurbitacea*). It is a drought tolerant crop which is cultivated chiefly in tropical, semi tropical and rigid regions of the world. Different varieties of watermelon are available and some of the varieties are: sugar baby, golden midget, star light, jubilee, yellow baby etc. They not only vary on their size (large or small) but also in their shape (oval, round or oblong) and colour of the flesh (red, orange and yellow). Sweet watermelon originates from West, not southern Africa, as previously believed, and the South African citron melon has been independently domesticated. The type specimen of the name **Citrullus lanatus,** prepared by a Linnaean collector in South Africa in 1773, is not the species now known as watermelon. Instead, it is a representative of another species that is sister to **C. ecirrhosus,** a tendril-less South African endemic. The closest relative of the watermelon is a West African species. Nuclear and plastid data furthermore reveal that there are seven species of **Citrullus**, not four as assumed. They are as follows- **Citrullus naudinianus, C. colocynthis, C. rehmi, Citrullus amarus,** with the synonyms **C. caffer** and **C. lanatus** var. **citroides, C. ecirrhosus** [3]. The species of watermelon which is widely available and eaten in Kolkata (India) is known as *Citrullus vulgaris*. It is round in shape, has dark green colored rind and red pulp which is sweet in taste.

C. vulgaris **plant** ***C. vulgaris*** **fruit**

According to Armen Takhtajan, the accepted name of this plant is given below-

1.2. Taxonomical classification [4]

Citrullus lanatus (Thunb.) Matsum. & Nakai. syn. *Citrullus vulgaris* Schrad.
Family : Cucurbitaceae
Order : Cucurbitales
Superorder : Violane
Subclass : Dilleniidae

II. AIMS AND OBJECTIVES

- To study the scientific literature of different species of watermelon.
- To compile the physicochemical properties, nutritional components and bioactive phytochemicals present in watermelon seed oil of different species.
- To map out the information regarding the therapeutic benefits and the physiological effects of watermelon seed oil.

III. REVIEWS ON WATERMELON SEED OIL

3.1. In-vitro analysis of watermelon seed oil

3.1.1. Analysis of some important fatty acids

NAME OF THE AUTHOR	NAME OF THE SPECIES	PALMITIC ACID (%)	STEARIC ACID (%)	OLEIC ACID (%)	LINOLEIC ACID (%)	LINOLENIC ACID (%)
Muhammad Waqar Azeem et.al, 2015[5]	***Citrullus lanatus***	15.47	12.61	20.53	50.78	0.14
Neuza Jorge et.al, 2015[6]		9.84	6.36	10.8	72.6	0.15
Edidiong A. Essien et.al, 2013[7]		10.57	8.333	13.65	62.14	5.293
S. Raziq et.al, 2012[8]	Sugar baby	15.0	11.2	21.2	51.1	
	QF-12	15.1	12.5	20.2	50.5	
	DWH-21y	16.2	13.8	23.0	45.1	
	Red circle-1885	14.3	12.3	20.2	51.2	
M.K. Sabahel Khier et.al, 2011[9]	***Citrullus lanatus*** White	13	18	11	68	
	Black	15	16	11	68	
OM Oluba et.al, 2008[10]		13.5	13.7	14.6	56.9	0.5
Odjobo Benedict Onoriode et.al, 2015[11]	***Citrullus vulgaris***	14.42	9.01	0.33	76.25	
Rahul Shivaji Adnaik et.al, 2015[12]		10.64	6.33	15.65	64.32	5.14
Zaharaddeen N. Garba et.al, 2014[13]		14.42	9.01	0.33	76.24	

NAME OF THE AUTHOR	NAME OF THE SPECIES	PALMITIC ACID (%)	STEARIC ACID (%)	OLEIC ACID (%)	LINOLEIC ACID (%)	LINOLENIC ACID (%)
Olubunmi Atolani et.al, 2012[14]		12.49	9.94		61.75	
T.A El-Adawy et.al, 2001[15]		11.30	10.24	18.07	59.64	0.35
Mirjana Milovanovic et al, 2005[2]	***Citrullus colocynthis***	12.42	10.2	14.2	62.2	1.02
Hiba Riaz et al, 2015[16]		4.30	1.83	33.66	54.70	2.15

3.1.2. Physicochemical characteristics

NAME OF THE AUTHOR	NAME OF THE SPECIES	SPECIFIC GRAVITY	REFRAC-TIVE INDEX	ACID VALUE	SAPONI-FICATION VALUE	IODINE VALUE	PER-OXIDE VALUE
Neuza Jorge et.al, 2015[6]	***Citrullus lanatus***		1.466 (40^0C)	5.05 mg KOH/ g	212.6 mgKOH/g	128.8 g/100g	3.40 meq/ kg
Muhammad Waqar Azeem et.al, 2015[5]			1.468 (40^0C)		198 mgKOH/g	107.51 g/100g	1.31 meq /kg
A.C.C. Egbuonu et.al, 2015[17]		0.87 (25^0C)		6.10 mg KOH/ g	205.3 mgKOH/g	28.51 g/100g	2.80 meq/kg
Duduyemi et.al, 2013[18]		0.85	1.47	2.37 mg NaOH/ g	183.13 mgNaOH/g	121.51 Wijs	
Edidiong A. Essien et.al, 2013[7]		0.9129	1.35	7.09 mg KOH/ g	220.19 mgKOH/g	114.94 g/100g	20.0 meq /kg
S. Raziq et.al, 2012[8]	Sugar baby		1.4665 (40^0C)		1.99.81 mgKOH/g	97.10 g/100g	2.90 meq O_2/kg
	QF-12		1.4668 (40^0C)		205.57 mgKOH/g	103.25 g/100g	5.06 meq O_2/kg
	DWH-21y		1.4667 (40^0C)		196.84 mgKOH/g	116.32 g/100g	3.30 meq O_2/kg
	Red circle-1885		1.4670 (40^0C)		190.20 mgKOH/g	114.00 g/100g	4.62 meq O_2/kg
M.K. Sabahel Khier et.al, 2011[9]	White	0.898 g/cm^3	1.468	16 %	609 mgKOH/g	85 mg/g	12 meq O_2/kg
	Black	0.894 g/cm^3	1.467	32 %	625 mgKOH/g	80 mg/g	9 meq O_2/kg
AA Taiwo et. al, 2008[19]	Oven dried (30^0C)	0.86 g/ml	1.459	13.40 mg NaOH/ g	117.81 mgKOH/g	59.69 g/100g	18.75 %
	Sun - dried	0.86 g/ml	1.458	8.98 mg NaOH/ g	115.94 mgKOH/g	58.42 g/100g	18.75 %
OM Oluba et.al, 2008[10]		0.93	1.45	3.5 mg KOH/ g	192.0 mgKOH/g	110.0 mg/g	8.3

NAME OF THE AUTHOR	NAME OF THE SPECIES	SPECIFIC GRAVITY	REFRAC-TIVE INDEX	ACID VALUE	SAPONI-FICATION VALUE	IODINE VALUE	PER-OXIDE VALUE
Odjobo Benedict Onoriode et.al, 2015[11]	***Citrullus vulgaris***	0.86 g/ml	1.458	9.58 %	255.26 mgKOH/g	58.54 g/100g	10 meq /kg
Rahul Shivaji Adnaik et.al, 2015[12]		0.915	1.46	6.48 mg KOH/ g	132.33 mgKOH/g	123 g/100g	21 meq /kg
Justina Y. Talabi et al, 2014[20]		0.7935	1.464	2.83 mg KOH/ g	130.53 mg KOH/g	142.50 mg/g	17.89 meq/kg
Zaharaddeen N. Garba et.al, 2014[13]		0.86		9.58 mg KOH/ g	255.26 mgKOH/g	58.54 g/100g	10 meq/g
T.A El-Adawy et.al, 2001[15]		0.919 (25^{0}C)	1.4696 (25^{0}C)	2.82 mg KOH/ g	201 mgKOH/g	115 g/100g	3.40 meq/kg
Mirjana Milovanovic et al, 2005[2]	***Citrullus colocynthis***	0.914 kg/dm^3 (20^{0}C)	1.4733 (20^{0}C)	1.00 mgKOH/ g	188 mgKOH/g	119 g/100g	7.9 mmol O_2/kg
Hiba Riaz et al, 2015[16]		0.8860 g/cm^3	1.4873 (20^{0}C)	3.91 mg KOH/ g	196.66 mgKOH/g	119.53 g/100g	6.97 meq O_2/kg

3.1.3. Mineral content

NAME OF THE AUTHOR	NAME OF THE SPECIES	Ca	Mg	Fe	Mn	Zn	Na	K
Zaharaddeen N. Garba et.al, 2014[13]	***Citrullus vulgaris***	1.40 ppm	5.75 ppm	2.10 ppm			4.80 ppm	3.80 ppm
M.K. Sabahel Khier et.al, 2011[9]	***Citrullus lanatus*** White	0.7 mg/g	11 mg/g	3.3 µg/ml	1.1 µg/ml	0.8 µg/ml		
	Black	1.1 mg/g	11 mg/g	7.5 µg/ml	0.2 µg/ml	2.5 µg/ml		

3.1.4. Tocopherol and vitamin-E content

NAME OF THE AUTHOR	NAME OF THE SPECIES	□-TOCO-PHEROL	γ-TOCO-PHEROL	□-TOCO-PHEROL	TOTAL TOCO-PHEROL	VITAMIN - E
Hiba Riaz et al, 2015[16]	***Citrullus colocynthis***	1.90 g/100g		0.32 g/100g		
Ejoh SI et. al, 2013[21]	***Citrullus vulgaris***					20.1 mg/100g
Neuza Jorge et.al, 2015[6]	***Citrullus lanatus***	11.7 mg/kg	715.6 mg/kg	20.8 mg/kg	748.1 mg/kg	

Muhammad Waqar Azeem et.al, 2015[5]		127.49 mg/kg		55.26 mg/kg		
NAME OF THE AUTHOR	**NAME OF THE SPECIES**	**□-TOCO-PHEROL**	**γ-TOCO-PHEROL**	**□-TOCO-PHEROL**	**TOTAL TOCO-PHEROL**	**VITAMIN - E**
S. Raziq et.al, 2012[8]	Sugar baby	195.6 mg/kg		12.3 mg/kg	207.9 mg/kg	
	QF-12	164.3 mg/kg		58.3 mg/kg	222.6 mg/kg	
	DWH-21y	122.0 mg/kg		9.1 mg/kg	131.1 mg/kg	
	Red circle-1885	120.6 mg/kg		20.0 mg/kg	140.6 mg/kg	

The variation of fatty acids, physicochemical properties, minerals, tocopherol and vitamin – E content among the same species of watermelon seed oil have been observed after the thorough review. The reason of this variation may be due to the differences in variety of the same species in different countries, and difference of soil and climatic condition of different geographical areas.

3.1.5. Antioxidant assay

Brine shrimp toxicity test and DPPH free radical scavenging assay were performed by Olubunmi Atolani et.al to determine the degree of acute and lethal toxicity and antioxidant potential of ***Citrullus vulgaris*** seed oil. The oil showed moderate cytotoxicity, and antioxidant potential of about 56% at 1 mg/ml concentration which was significantly more than the reference compounds α –tocopherol [14]. Neuza Jorge et.al, in the year 2015 estimated 30.6% DPPH free radical scavenging activity in ***Citrullus lanatus*** seed oil which might be due to the presence of high amount of total phenolic compounds (1,428.9 ± 17.00 mg/kg) and total tocopherol (748.1 mg/kg) [6].

3.2. Animal Experiments on the nutritional and physiological effects of watermelon seed oil

3.2.1. Edibility of the oil

The characteristics and composition of the crude oil extracted from *Citrullus colocynthis* seeds were examined. Feeding the oil at 5 and 10% of the diet to one- day- old chicks had no significant effect on body weight, feed consumption or feed efficiency as compared to feeding corn oil at the same levels. The oil did not show any toxicity effects too. Based on these results, *Citrullus colocynthis* oil might be of some potential use for animal feed and/or human consumption [22].

3.2.2. Effect on growth

Olarewaju M. Oluba et.al and George O. Eidangbe et.al. in the year 2011 and 2010 respectively showed the effect of feeding ***Citrullus lanatus*** (Egusi melon) seed oil diet on body weight of rats after 6weeks experimental period. Both the study showed that there were insignificant differences in food intake among the control and experimental group of rats but significantly ($p < 0.05$) less weight gained by the egusi melon seed oil fed group of rats than that of the control group, which might be due to low total body fat content among the experimental group of rats [23, 24].

3.2.3. Cardioprotective effect

Olarewaju M. Oluba et.al and George O. Eidangbe et.al. in the year 2011and 2010 respectively showed the effect of feeding ***Citrullus lanatus*** (Egusi melon) seed oil (EMO) diet on lipid profile of rats after experimental period of 6weeks. These 2 studies showed that serum and hepatic lipid profile improved significantly among the EMO fed group of rats [23, 24]. O. Oluba et.al conducted a study on EMO in the year 2007. The extracted oil was used in diet formulation and fed (as a supplement to cholesterol-based diet) to rats for a period of 6 weeks to determine its effect on serum lipids. EMO with a rich content of polyunsaturated fatty acid was found to produce a significant reduction ($p<0.05$) in serum total, free and esterified cholesterol and triglyceride concentrations. Histopathological examination showed that egusi melon oil reduced foam cell formation and inhibited smooth muscle cell migration in the blood vessel of rats [25].

3.2.4. Hepatoprotective effect

Citrullus lanatus seed oil; CLSO (125mg) and CLSO (250mg) were administered orally for 10 days in CCl4 induced rats and compared with standard silymarin (100 mg/kg) orally. ALT, AST and ALP levels, which were increased due to CCl4 induced liver damage decreases significantly among the treated groups and are comparable with standard drug silymarin [26]. O. Oluba et.al conducted a study on EMO in the year 2007. The extracted oil was used in diet formulation and fed (as a supplement to cholesterol-based diet) to rats for a period of 6 weeks to determine its effect on serum activities of LDH (Lactate dehydrogenase), ALT (alanine Aminotransferase), AST (aspartate aminotransferase), and γ-GT (gamma-glutamyl transpeptidase). Significant reduction ($p<0.05$) in serum activities of the enzymes were observed in the egusi melon oil-fed rats [25].

3.2.5. Anti-diabetic effect

Study conducted by N. Sebbagh et.al., evaluated the differential effects of diets enriched with *C. colocynthis*, sunflower or olive oils on the pancreatic β-cell mass in streptozotocin (STZ)-induced diabetes in rats. Finally, at the end of the experiment, the olive- and sunflower-oil supplementation showed less protective effect compared with *C. colocynthis* oil against hyperglycaemia. Furthermore, the HOMA (Homeostasis Model Assessment) scores appear to support an effect of *C. colocynthis* to increase insulin action. Taken altogether, the data suggest the partial preservation of functional β-cell mass in the latter diet group, emphasizing the specific effect of *C. colocynthis* compared with both olive and sunflower oils [27].

3.2.6. Effect on sex hormones

The effect of some traditionally extracted edible seed oils (sesame, peanut and melon oils) on some sex hormones – prolactin, progesterone, testosterone, estradiol, luteinizing hormone (LH) and follicle stimulating hormone (FSH) of albino wistar rats was studied. The results indicated that 5% and 10% supplemented *C. lanatus* seed oil caused significant increase ($p < 0.05$) in prolactin level (with a corresponding decrease in progesterone), LH, estradiol and testosterone relative to the controls [28].

IV. CONCLUSIONS AND RECOMMENDATIONS

Keeping in view the results reported in the above research articles, it is reasonable to say that watermelon seed oil could be a potential source of nutrients especially the essential fatty acids (Oleic and Linoleic acids), minerals (Na, K, Mg, Fe and Zn), antioxidant compounds (total phenol, α-tocopherol and vitamin-E). According to most of the researches the values of the physicochemical characteristics of watermelon seed oil are within the recommended limits and therefore it could be a good source of cooking and frying oil. After going through its comprehensive toxicological investigation, nutritional and physiological benefit, as revealed from different animal studies, it may be recommended that watermelon seed oil must be commercially exploited to be used in different nutraceuticals and functional food commodities and also a potential antidote for fighting against various ailments. Still there is an ample scope of research to expose hitherto unknown bioactive phytoconstituents responsible for the positive health benefits of the seed oil.

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