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Efficacy of Coconut Oil (*Cocos nucifera* L.) Fortification on Liver Functions Rats with Induced Hypothyroidism

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ABSTRACT

The aim of the present study was conducted to investigate the effect of coconut oil fortification on rats with induced hypothyroidism. Thirty adult male albino rats (Sprague-Dawley strain), weighing about (200±10g) were divided randomly into two main groups as follow: the first group (-ve control= 6 rats) was fed on basal diet. The second group (24rats) were fed on basal diet and injected with 6-n-propyl-2-thiouracil (PTU) (10 mg/kg Body weight i.p.) for 15 days to induce hypothyroidism , then divided into 4 subgroups from group 2 to group 5. Supgroup 2 (+ve control) fed on basal diet. Supgroups 3, 4 and 5 fed on basal diet fortified with 5, 7.5 and 10% coconut oil, respectively. At the end of the experimental period (six weeks), animals were scarified for blood collection. Thyroid hormones (FT3 and FT4), thyroid-stimulating hormone (TSH), alanine aminotransferase (ALT), aspartate aminotransferase (AST), total bilirubin, malondialdehyde (MDA) and catalase (CAT) were determined. Hypothroidismic rats which fed on diet fortified with coconut oil at the different levels had significant ($P<0.05$) decrease in serum TSH, liver function enzymes and MDA levels and had significant ($P<0.05$) increase in serum thyroid hormones (FT3 and FT4) and CAT compared with +ve control group. It can be suggested that fortification with coconut oil could be used as a suitable therapy for hypothyroidism patients.

Keywords: coconut oil, hypothyroidism, thyroid hormones, liver functions, rats.

Introduction

The thyroid gland is an endocrine gland in the neck, consisting of two lobes connected by an isthmus. It is responsible for secreting hormones that regulates body metabolism (Skarulis and Stack, 2015). The hormones also have many other effects including those on development. The thyroid hormones triiodothyronine (T3) and thyroxin (T4) are created from iodine and tyrosine. The thyroid also produces the hormone calcitonin, which plays a role in calcium homeostasis (Hall and John, 2011). Thyroxine (T4) and tri-iodothyronine (T3) are necessary for the physiological functions of almost all body tissues (Sharma *et al*., 2018).

Disorder of thyroid function may produce various subclinical or clinical manifestations (Chaker *et al*., 2017), such as weight change, sweating, exhaustion, lethargy, cold resistance, voice change, an increase in metabolism of cholesterol, decrease in metabolic rate. Sometimes, there may be swelling of the front part of the neck due to goiter diseases (Louzada and Carvalho, 2018). Hypothyroidism is related to oxidative stress due to excessive free radical growth (Chakrabarti *et al*., 2016).

Coconut oil (*Cocos nucifera* L.), is an edible oil extracted from the kernel or meat of mature coconuts harvested from the coconut palm (Berlin, 2015). It is a colorless to brown-yellow edible oil derived from mature coconuts (Babu *et al*., 2014). Coconut oil comprises 99.9% fatty acids; of these, 91.9% are saturated fatty acids, 6.4% are monounsaturated fatty acid acids and 1.5% are polyunsaturated fatty acids, and coconut oil contains no dietary cholesterol (PHE, 2015). Coconut oil fatty acids are lauric , myristic and palmitic acids. Virgin coconut oil has been found to contain up to seven times higher concentrations of polyphenols than standard coconut oil, with total polyphenol contents of up to 80 mg gallic acid equivalents/100 g oil reported in virgin coconut (Marina *et al*., 2009).Coconut oil has been renowned for its medicinal and nutritional value. Virgin coconut oil is rich in medium chain fatty acids, phenolic, and polyphenols which made it beneficial as an antioxidant source (Chew, 2019).

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Studies on the biological effects of coconut oil have proven that it ameliorates oxidative stress by boosting the antioxidant defense system, mopping up free radicals and reducing lipid peroxidation (Dosumu *et al*., 2010).

In recent years, coconut oil has emerged as the heart healthy alternative to butter. Researchers also described coconut oil with antibacterial and antifungal properties when used as a topical treatment on human skin and hair (Vaughn *et al*., 2018).

Zakaria *et al*. (2011) reported that coconut oil have protective effects on the liver of rats . The tested animals (divided into 9 groups of 6 rats) were males weighing 180-220 g, which were fed with VCO in amounts of 1.5 and 10 ml/ kg for 7 days. The results confirmed that the use of the coconut oil supplement lowers liver damage in animals. It has also been reported to suppress microbial and viral activities (Van Immerseel *et al*., 2004), promote weight loss and enhance thyroid function (Takeuchi *et al*., 2008). Therefore, this study was conducted to evaluate the efficacy of coconut oil fortification on rats with induced hypothyroidism.

Materials and Methods

Materials:

Coconut oil was purchased from Agriculture Research Center, Giza, Egypt.

Casein, cellulose, vitamins mixture, choline bitartrate and L-cysteine were obtained from the Global Company for Chemicals Trading, Cairo, Egypt. Minerals mixture and formalin were purchased from El-Gomhoria Company, Cairo, Egypt. Propylthiouracil (PTU) was obtained from Amoun Pharmaceutical Company, El-Obour City, Cairo, Egypt. Kits for blood analysis were purchased from Gama Trade Company for Chemicals, Cairo, Egypt. Rats were purchased from experimental animal's station, agricultural research center, Giza, Egypt.

Methods:

Induction of Hypothyroidism in Rats:

Propylthiouracil (PTU) was used for inducing hypothyroidism in this study. Hypothyroidism was induced in normal healthy adult male rats according to Sener *et al*. (2006) using PTU (10mg/kg BW/day) by intraperitoneal (i.p.) injection for 15 days. Propylthiouracil injections were repeated once daily. Then, blood samples were obtained from eyes by capillary tube, centrifuged to obtain serum, which was analyzed to compare the values of serum (FT3, FT4 and TSH) to the negative control rats. Hypothyroidism is defined as lower serum FT3, FT4 and higher TSH (Dons *et al*., 2009).

Diet Composition and Experimental Animal Design

The basal diet was formulated according to AIN-93M diet (Reeves *et al*., 1993). After acclimatization period (7days), rats were divided into two main groups. The first main group (n=6) was fed on the basal diet during the experimental period (six weeks) and kept as a negative control (-ve). The rest of the animals (n = 24) were injected with PTU for hypothyroidism induction as mentioned before. Hypothyroidismic groups were divided into four subgroups (6 rats each) and were fed on the following diet schema for four weeks, the remainder rats (n= 24) were assigned to one of the following diet scheme for four weeks as follow: Subgroup (1), hypothyroidismic rats were fed on basal diet (positive control). Subgroups from (2 to 4), hypothyroidismic rats were fed on basal diet and fortified with 5, 7.5 and 10 % coconut oil respectively. At the end of the experimental period (6 weeks), rats were fasted overnight before sacrificing and the blood samples were collected from each rat and were centrifuged to obtain serum.

Biological Evaluation:

Biological evaluations were carried out by determination of feed intake (FI) which was recorded every day throughout the experimental period. Body weight gain (BWG%) and feed efficiency ratio (FER) were determined according to (Chapman *et al*., 1959). Body mass index (BMI) was determined according to (Shabbir *et al*., 2016).

Biochemical Analysis of Serum:

Free triiodothyronine (FT3), Free thyroxine (FT4) and Thyroid-stimulating hormone (TSH) were determined according to the method described by (Shamsian *et al*., 2016). Aspartate aminotransaminase (AST), alanine aminotransaminase (ALT) and total bilirubin were determined according to the method described by Young, (2001). Malondialdehyde (MDA) and catalase (CAT) were determined according to Draper and Hadley, (1990) and Aebi, (1984), respectively.

Statistical Analysis:

Results were expressed as the mean ± standard deviation (SD). Data were statistically analyzed for variance using "ANOVA" test at $P \leq (0.05)$ by SPSS statistical software, version 20 was used for these calculations (Armitage and Berry, 1987).

Results

The effect of diet fortified with coconut oil on FI, BWG, FER and BMI of rats with induced hypothyroidism are shown in Table (1). Mean value of feed intake of positive control group was 15.00g/d while in negative control was (20.00g/d).Tested groups which fed on 5, 7.5 and 10% coconut oil had mean values 17.00, 19.00 and 20.00 g/d. All tested groups had mean feed intake values higher than positive control group.

Table 1: Effect of diet fortified with coconut oil on FI, BWG, FER and BMI of hypothyroidismic rats

Parameters / Groups	FI (g/d)	BWG (%)	FER	BMI(g/cm²)
Control (-)	20.00	29.06±5.15^{a}	0.02 ±0.001^{a}	0.592±0.058^{a}
Control (+)	15.00	14.91±4.30^{c}	0.013±0.002^{c}	0.533±0.031^{d}
5% Coconut oil	17.00	18.44 2.67^{c}	0.014 ±0.003^{c}	0.554±0.035^{c}
7.5 % Coconut oil	19.00	24.20±5.03^{b}	0.016 ±0.002^{b}	0.562±0.029^{b}
10% Coconut oil	20.00	28.17 ±6.07^{a}	0.02 ±0.004^{a}	0.579±0.027^{b}

Mean values are expressed as means ± SD.
Means with different superscript letters in the same column are significantly different at $P \leq 0.05$.

Regarding BWG%, during the experimental period, positive control group showed significant reduction in body weight ($P \leq 0.05$) compared to the negative control group 14.91±4.30 and 29.06±5.15 , respectively. Body weight gain % values of hypothyroidismic rats fed on diets fortified with coconut oil 5, 7.5 and 10% were significantly increased ($p \leq 0.05$) compared to that of positive control group in the following magnitude of increasing order 18.44 2.67, 24.20±5.03 and 28.17 ±6.07, respectively. Fortification with coconut oil with 10 % induced highest increase in weight gain as no significant difference was observed between this level and that value of the control negative group.
Regarding FER, positive control group had significant decrease than the negative control ($P \leq 0.05$) with a mean values of 0.013±0.002 and 0.02 ±0.001,respectively. Hypothyroidismic rats fed on diets fortified with coconut oil at the three levels (5 ,7.5 and 10%) had significant increase in FER with mean values of 0.014 ±0.003, 0.016 ±0.002 and 0.02 ±0.004,respectively compared to the positive control group. The lowest mean value of FER was observed in the hypothyroidismic group received 5% coconut oil ,while the greatest improvement was observed in the hypothyroidismic group received 10% coconut oil compared with other groups as no significant difference was observed between this level and that value of the control negative group.

Results revealed that, the BMI of the positive control group was significantly lower than that of negative control group ($P \leq 0.05$) with mean values of 0.533±0.031 g/cm² and 0.592±0.058 g/cm², respectively. Hypothyroidismic rats fed on diets fortified with coconut oil at the three levels (5 ,7.5 and 10%) showed significant increase in BMI with mean values of 0.554 ±0.035 g/cm², 0.562 ±0.029 g/cm² and 0.579 ±0.027 g/cm² ,respectively compared to the positive control group. The greatest improvement of BMI was observed in the hypothyroidismic group received 10% coconut oil compared with other groups , While the lowest mean value of body mass index was observed in the hypothyroidismic group received 5% coconut oil .

Results as shown in Table (2). Both of serum FT3and FT4concentration were significantly ($P \leq 0.05$) decreased as a result of PTU injection compared with the negative control group with mean values of 3.36 ± .81 pg/dl vs. 5.05 ± 0.14 pg/dl for serum FT3, 1.20 ± .09 ng/dl vs. 2.07 ± 0.15 ng/dl for serum FT4. Furthermore, both of serum FT3and FT4 concentration in hypothyroidismic rats were significantly ($P \leq 0.05$) increased after fortification with the different levels of either coconut oil compared with the positive control group.

Table 2: Effect of diet fortified with coconut oil on serum thyroid hormones profile of hypothyroidismic rats.

Parameter / Groups	FT3 (pg/dl)	FT4 (ng/dl)	TSH (ng/ml)
Control (-)	5.05 ± 0.14 [a]	2.07 ± 0.15 [a]	1.15 ± 0.004 [d]
Control (+)	3.36 ± 0.81 [c]	1.20 ±0.09 [c]	3.39 ± 0.06 [a]
5% Coconut oil	3.47 ± 0.15 [c]	1.28 ± 0.02 [c]	3.30 ± 0.09 [a]
7.5 %Coconut oil	4.09 ± 0.27 [b]	1.71 ± 0.08 [b]	2.57 ± 0.08 [b]
10 % Coconut oil	4.63 ± 0.19 [a]	1.97± 0.05 [a]	1.96 ± 0.02 [c]

Mean values are expressed as means ± SD.
Means with different superscript letters in the same column are significantly different at P≤ 0.05.

When hypothyroidismic rats were fed on diet fortified with 5 and 7.5 and 10% coconut oil , serum FT3 and FT4 concentrations were significantly improved with mean values of 3.47 ± 0.15 pg/dl , 4.09 ± 0.27 pg/dl and 4.63 ± 0.19 pg/dl , respectively for serum FT3 , 1.28 ± 0.02 ng/dl , 1.71 ± 0.08 ng/dl and 1.97± 0.05 ng/dl for serum FT4 compared to the positive control group. The most pronounce improvement in FT3 and FT4 activities were observed in the group of hypothyroidismic rats fortified with 10% coconut oil in the diet as no significant difference was observed between it and FT3 and FT4 values of the control negative group.

The serum level of TSH was increased significantly ($P \leq 0.05$) in the hypothyroidismic control positive group compared to the negative control group which representing 3.39 ± .06 ng/ml vs. 1.15 ± 0.004 ng/ml, respectively.

Fortification diet with coconut oil at the three different levels to HT rats resulted in significant ($p \leq 0.05$) decrease in TSH levels compared to the positive control group. Which representing 3.30 ± 0.09 ng/ml (for 5% coconut oil), 2.57 ± 0.08 ng/ml (for 7.5% coconut oil) and 1.96 ± 0.02 ng/ml (for 10% coconut oil), respectively. Interestingly, the most pronounced increased in TSH level was observed when rats were fed on diet fortified with 10% coconut oil.

Results of liver enzymes concentration of hypothyroidismic rats fed on different levels of coconut oil are presented in Table (3). Induction of hypothyroidism significantly ($P<0.05$) increase both ALT and AST values in serum of positive control group compared to the negative control group . The activity of ALT significantly decreased ($p\leq0.05$) in the hypothyroidismic groups fortified with coconut oil at 5, 7.5 and 10% levels of intake compared with the positive control group.

Table 3: Effect of Diet Fortified with Coconut Oil on Serum Liver Functions of Hypothyroidismic Rats

Parameters / Groups	ALT (u/l)	AST (u/l)	Total Bilirubin (mg/dl)
Control (-)	46.74 ± 8.76 [c]	82.44 ± 8.93 [c]	0.18 ± 0.002[c]
Control (+)	62.88±7.45 [a]	104.07±9.96 [a]	0.23 ± 0.05 [a]
5% Coconut oil	58.66 ± 5.99 [a]	98.70 ±10.04[a]	0.22 ± 0.09 [a]
7.5 % Coconut oil	52.79 ± 6.84 [b]	90.05 ±9.76 [b]	0.21 ± 0.08 [bc]
10 % Coconut oil	49.21± 5.73 [b]	85.10 ±7.72 [c]	0.20 ± 0.04 [b]

Mean values are expressed as means ± SD.
Means with different superscript letters in the same column are significantly different at P≤ 0.05.

The highest decreasing in ALT concentration was observed when rats were fed diet fortified with 10% coconut oil. The addition of the tested three levels (5, 7.5 and 10 %) of coconut oil caused reduction in AST concentrations compared to the positive control group. The most pronounce improvement in AST activities was observed in the group of hypothyroidismic rats fortified with 10%

coconut oil as no significant difference was observed between it and AST value of the control negative group.

While Induction of hypothyroidism caused significant increase in total bilirubin values in serum of positive control group compared to the negative control group representing 0.23 ± 0.05 mg/dl vs. 0.18 ± 0.002 mg/dl, respectively. The concentration of total bilirubin significantly decreased ($p \leq 0.05$) in the hypothyroidismic groups fortified with coconut oil at 5, 7.5 and 10% levels of intake compared with the positive control group. These values were 0.22 ± 0.09 u/l, 0.21 ± 0.08 u/l and 0.20 ± 0.04, respectively. The most pronounce improvement in total bilirubin activities was observed in the groups of hypothyroidismic rats fortified with 7.5 and 10 % coconut oil compared with the negative control group.

The effect of diet fortified with coconut oil on serum MDA of hypothyroidismic rats was illustrated in Table (4) .The mean value of malondialdehyde concentration of the HT control group was significantly ($P \leq 0.05$) increased compared to the negative control group which representing 250.00 ± 42.22 µmol/dL vs. 97.60 ± 8.98 µmol/dL , respectively. When rats were fed on coconut oil at any level of intake their serum malondialdehyde concentrations were decreased significantly compared with the hypothyroidismic rats. The lowest mean value of MDA was observed in the hypothyroidismic group received 5% coconut oil ,while the greatest improvement was observed in the hypothyroidismic group received 10% coconut oil compared with the negative control group .

Table (4): Effect of diet fortified with coconut oil on MDA and CAT of hypothyroidismic rats

Parameters / Groups	MDA (µmol/dL)	CAT (mM/L)
Control (-)	97.60 ± 8.98 ^{e}	75.53 ± 4.38 ^{c}
Control (+)	250.00 ± 42.22 ^{a}	37.00 ± 3.16 ^{e}
5% Coconut oil	172.32 ± 15.25 ^{b}	52.32 ± 3.05 ^{d}
7.5 %Coconut oil	133.32 ± 18.37 ^{c}	96.33 ± 11.54 ^{b}
10 % Coconut oil	112.32 ± 9.28 ^{d}	110.32 ± 19.13 ^{a}

Mean values are expressed as means ± SD.
Means with different superscript letters in the same column are significantly different at $P \leq 0.05$.

Table (4) illustrated also the effect of diet fortified with coconut oil on serum CAT of hypothyroidismic rats. The level of catalase concentration of the HT control rats was significantly ($P \leq 0.05$) decreased compared to the negative control group which representing 37.00 ± 3.16 mM/L vs. 75.53 ± 4.38 mM/L, respectively. The serum catalase activity of treated hypothyroidismic with different levels of coconut oil were significantly ($P \leq 0.05$) increased compared to the positive control group. The greatest mean value of CAT was observed in the hypothyroidismic group received 10% coconut oil ,while the lowest mean value was observed in the hypothyroidismic group received 5% coconut oil compared with the negative control group .

Discussion

Virgin coconut oil is known to have beneficial health effects. Although it is composed mainly of saturated fatty acids. The main fatty acids found are lauric, palmitic and myristic acids. Most of the fatty acids in virgin coconut oil are composed of medium chain fatty acids. So, they are directly absorbed by intestine and sent to liver to be used as energy source (Boemeke *et al*., 2015), and protects the body from disease (El-Shemy, 2018). Natural oils such as virgin coconut oil (VCO) is evolving as functional foods due to its health promoting pharmacological activities reported in published literature (Famurewa *et al*., 2017and Ogedengbe *et al.*, 2018).

The current study was mainly focused to indicate the effect of coconut oil for hypothyroidismic rats which injected with PTU. Hypothyroidism is a metabolic disorder which is usually associated with disturbance in FI which is reflected on body weight of individual (Cadnapaphornchal *et al*., 2003). In the present study the amount of FI and BWG of hypothyroid rats were less than the normal negative control group. These results are in agreement with (Mohamed *et al*., 2016).

It is well known that thyroid hormones are necessary for growth. Inducing HT in this study leads to a reduction in the body weight of rats, which may be explained by reduced thyroid hormone

levels as demonstrated by this experiment results and confirmed by previous studies carried out on rats (Aragão *et al*., 2007 and Amara *et al*., 2010).

In the present study rats were inducted with PTU showed hypothyroidism. This was evidenced biochemically by reduction in serum TH levels of (FT3 and FT4) with increase in serum TSH level compared to the normal control rats. These results are in agreement with Rabeh and El-Ghandour, (2016) and Negm, (2019). Serum concentrations of thyroid hormones (T3, T4) and TSH are commonly used as reliable indicators of the thyroid function in humans and experimental animals (Kelly, 2000).

Propylthiouracil effects may be due to inhibiting the TH synthesis and blocking the transformation of T4 to T3 (Ökten *et al*., 1996). Deiodinase is strongly inhibited by the anti-thyroid drug PTU (Norris, 2007). As the prohormone T4 is then converted to its biologically active form T3 by iodothyronine deiodinase (Bianco *et al*., 2002). The reduction of thyroid hormone levels of the present study are in the line with those observed by Khalawi *et al*., (2013).

Furthermore, Haiying *et al*., (2006) found that HT subjects were diagnosed with biochemical parameters of T3 and T4 below the normal ranges and TSH above the normal range. It was also agreed with results of Zbucki *et al*., (2007) who found a significant decrease in the plasma concentration of T3 and T4 of HT rats whereas TSH level was significantly increased compared to the negative control rats.

The present results indicated that increased in concentration of FT3, FT4 and a significant ($P \leq 0.05$) decrease in the TSH, compared to the positive control group. These in the line of this Negm, (2019) who found that ,the supplementation with VCO caused significant ($P \leq 0.05$) increased in concentration of FT3, FT4 and a significant ($P \leq 0.05$) decrease in the TSH, compared to the positive control group. Bhanja and Chainy, (2010) reported that hypothyroidism causes oxidative stress in rats, this leads to tissue damage and apoptosis. Fumarola *et al*., (2010) stated that PTU inhibits iodine oxidation and monodotyrosine ionization. It is also prevented the coupling stage and inhibited the peripheral conversion of T4 to T3. So, it suppresses the synthesis of thyroid hormones by blocking the activity of thyroid peroxidase (Sue *et al*., 2012).

Dietary fatty acids have marked influence on functioning of thyroid gland (Gupta *et al*., 2009). Some authors suggest that isoflavones have a moderate or no effect on the role of thyroid (Dillingham *et al*., 2007). Meanwhile others showed that isoflavones suppress the function of thyroid (Sathyapalan *et al*., 2011). Gupta *et al*. (2009) who found that coconut oil fed rabbits had a significant reduction in TSH levels. Rabeh, (2017) who found that, virgin coconut oil, curcumin, vitamin D or their mixture increased the level of thyroid hormones and lowered the level of TSH. Such effects may be due to high content in VCO of polyphenolic and other antioxidants. Rabeh, (2017) and Takeuchi *et al*., (2008) who reported that coconut oil enhances thyroid functions.

The supplementation with Iron, Zinc, Vit.E and Vit.C significantly ($P<0.05$) increased the concentration of thyroid hormones FT4 and FT3 and also caused a significant ($P<0.05$) decrease in the mean value of TSH, compared with control positive group. There are several trace elements that are needed for the normal function, synthesis and metabolism of the thyroid gland (Rabeh and El-Ghandour, 2016). Coconut oil is a source of vitamin E and polyphenols (Rabeh, 2017).

In the present study showed that hypothyroidism caused significantly increase ($P \leq 0.05$) activity of ALT, AST and bilirubin in rats of the control positive group compared to the negative control group. This may be due to the disruption occurred in liver functions. Also the results showed that, feeding rats suffering from hypothyroidism with VCO led to a significant decrease ($P \leq 0.05$) in AST and ALT levels comparing with the positive control group. There in the line of Negm, (2019). Margata, (2018) who shown that rats fed with VCO and hydrolyzed virgin coconut oil (HVCO) significantly decreased ALT and AST levels in dyslipidemic rats.

Thyroid hormones control the basal metabolic rate of all body cells including hepatocytes and thus modulate the function of the liver. In exchange, the liver metabolizes thyroid hormones and controls their endocrine systemic effects. Therefore, thyroid dysfunction may disturb liver function (Khan *et al*., 2010).Carrion *et al*., (2010) who recorded a positive relationship between thyroid hormones and liver enzymes. Thyrotoxicosis is generally associated with a variety of liver dysfunction.

According to Siddalingaswamy *et al*., (2011) and Pretha *et al*., (2013) virgin coconut oil ables to positively influence liver functions. Rabeh and El-Ghandour, (2016) and Aisuodionoe *et al*., (2018)

who reported that virgin coconut oil improves metabolic parameters, antioxidant enzyme activities, reduces oxidative stress and lipid peroxidation in diabetes. Famurewa *et al*., (2018) who mentioned that beneficial effects of virgin coconut oil on antioxidant hepatic defense system rats. Alteration in liver enzymes is an early marker for the tissue damage by toxic substances or disease conditions. SGOT and SGPT are liver enzymes that occur during hepatic cells damage (Mohammed and Luka, 2013) .Also, (El-Shemy, 2018) who reported that coconut oil removed the liver cell damage.

Bilirubin is a yellow pigment produced when heme is catabolized. Hyperbilirubinemia may result from ineffective erythropoiesis, impaired ability of the liver to excrete normal amounts of bilirubin, or obstruction of excretory ducts of the liver (Olaleye *et al*., 2010) . Otuechere *et al*., (2013), reported that the significant reduction in the level of total bilirubin in the serum of trimethoprim-sulfamethoxazole (TMP-SMX) pretreated rats suggested the hepatoprotective potential of VCO against TMP-SMX induced hepatotoxicity.

In the present study found that hypothyroidism caused significantly increase ($P \leq 0.05$) activity of MDA and decrease CAT in rats of the control positive group compared to the negative control group. Also the results showed that, feeding rats suffering from hypothyroidism fortified with VCO led to a significant decreased ($P \leq 0.05$) in MDA and increased in CAT levels comparing with the positive control group. Also the results of showed the same trend Haribabu *et al*., (2013) and Negm, (2019).

Also, Famurewa *et al*., (2018) reported that the level of malondialdehyde (MDA), a lipid peroxidation marker, remarkably reduced and activities of hepatic antioxidant enzymes-superoxide dismutase (SOD), catalase (CAT), and glutathione peroxidase (GPx) were markedly increased in VCO diet-fed rats.

Malondialdehyde is an oxidative stress marker that can be used to measure the extent of lipid peroxidation (Gaweł *et al*., 2004). In hypothyroid subjects, MDA level was found to be higher in oxidative stress (Lakshmi *et al*., 2013). Phytoestrogens can play an antioxidant role not only by breaking down reactive oxygen species, but also by stimulating antioxidant enzyme activity (Taha *et al*., 2014). Marina *et al*., (2009) and Yeap *et al*., (2015) demonstrated the antioxidative potential and powerful countermeasures of virgin coconut oil polyphenols against lipid peroxidation in tissues.

Iranloye *et al*., (2013) suggested that virgin coconut oil reduces oxidative stress by boosting the antioxidant defense system, scavenging free radicals and reducing lipid peroxidation another independent study suggested that fresh coconut oil can reduce oxidative stress associated with diabetes mellitus. Famurewa *et al*., (2018) showed that virgin coconut oil decreased malondialdehyde (MDA) levels, and increased activities of hepatic antioxidant enzymes superoxide dismutase (SOD). Virgin coconut oil contains high unsaponifiable lipid components like vitamin E and polyphenols, tocotrienols, tocopherols, β carotene and phytosterol in stabilizing cell membranes by preventing alterations in membrane lipid polarity and fluidity (Jaarin *et al*., 2014).

Virgin Coconut Oil stimulated the antioxidant enzymes activity and decreased the MDA and glutathione levels in healing wounds. This inhibition in lipid peroxidation promoted fibroblast proliferation, neovascularization, and healing process (Nevin and Rajamohan, 2010). In addition, blending of VCO with groundnut oil or olive oil was proven to be effective in inhibiting LDL oxidation, and stimulating the activity of hepatic antioxidant enzymes (Nagaraju and Belur, 2008) .

The antioxidant activity of virgin coconut oil is due to the high composition of polyphenol compounds in the oil (Nevin and Rajamohan, 2006 and Marina *et al*., 2009). Marina *et al*., (2009), estimated the total phenolic content of VCO to be in the range of 7.78–29.18 mg GAE/100 g oil, which is significantly higher than the refined, bleached, and deodorized coconut oil. The major polyphenols in VCO are ferulic acid and p-coumaric acid. Polyphenols are stronger as antioxidants than vitamins C and E *in vitro* on the molar basis (Rice-Evans *et al*., 1997) .

The antioxidant properties of ferulic acid have been established. Ferulic acid belongs to phenoxy carboxylic acid family (Graf, 1992). Toda *et al*., (1991), have proven that ferulic acid has the ability to scavenge the superoxide radical and suppress the lipid peroxidation induced by superoxide anion. Superoxide radicals can enhance bone resorption by degrading matrix proteins, making the bones weak and easily digested by enzymes (Banfi *et al*., 2008).

The effects of ferulic acid and superoxide dismutase as antioxidants were equal in magnitude and this characteristic made it superior to caffeic acid and p-coumaric acid as an antioxidant. In addition, the effect of ferulic acid as inhibitor of lipid peroxidation was similar to the effect of α-

tocopherol (Toda *et al*., 1991). Gastelluccio *et al*., (1996), reported that ferulic acid was more potent as an antioxidant against LDL oxidation than ascorbic acid. It seems that VCO derives most of its effects from the free-radical scavenging and antioxidant properties of ferulic acid.

The antioxidant power of ferulic acid is due to its ability to effectively end the terminal radical chain reactions, since any free radical colliding with ferulic acid molecule can easily extract a hydrogen atom from the phenolic hydroxyl group to form a phenoxy radical which is considered a highly stable compound (Graf, 1992). This phenoxy radical is unable to initiate or propagate the reactive chain reaction. This stability belongs to easy formation and lack of reactivity of phenoxy radical. Virgin coconut oil is rich in polyphenols and these antioxidants may contribute to the increased levels of antioxidant enzymes, which subsequently reduce lipid peroxidation and inflammation in VCO-treated mice (Zakaria *et al*., 2011) .

In conclusions, fortification with coconut oil improved hypothyroidism especially at 10% by the reduction of liver functions, TSH and MDA levels and increasing the value of thyroid hormones (FT3 and FT4) and CAT contents.

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