Chapter

Role of Red Palm Oil in Male Obesity and Infertility Prevention

Folorunso A. Olabiyi, Yapo G. Aboua and Thomas K. Monsees

Abstract

The African continent has wide, varied, and rich plant diversity due to its climate. Some of these plants and their products have received tremendous attention due to their benefits in treating and managing ailments that plagues humanity. Red palm oil (RPO) is one of such natural products that have immense nutritional value with ability to ameliorate cardiac- and reproductive-related disorders. In this review article, the current knowledge on the potential of RPO as a phytomedicine to lessen or even prevent the negative impact of obesity on general health status and male fertility was evaluated. This study was done using electronic databases such as PubMed, Scopus, Science Direct, Google Scholar and Web of Science. The study revealed some controversies and inconsistent reports on the effect of RPO on obesity and male fertility which needs further research using appropriate experimental models of obesity. Obesity is known to disrupt male fertility by causing changes to the hypothalamic- pituitary-gonadal axis, thus impairing steroidogenesis and spermatogenesis. As spermatozoa are extremely sensitive towards oxidative stress, a carefully balanced daily supplementation of normal diet with antioxidant-rich RPO might be useful to protect spermatozoa and preserving male fertility. RPO was shown to be useful to protect against or ameliorate toxin- or medical condition-induced male infertility. Also, RPO is packed with powerful antioxidants like carotenoids and vitamin E which helps to prevent cell damage. However, its role in obesity prevention remains a debate.

Keywords: Obesity, male Infertility, Red palm oil (RPO), male Reproduction, medicinal plant

1. Introduction

In recent time, obesity is considered one of the most critical public health concerns due to its severe physiological and economic implications. The scourge was once considered a problem only in the developed nations [1]. Contrarily, it has been reported that people living in low income countries with less affluence are not spared. In this case, the obesity could be associated with stress, alcoholism and poor nutrition due to poverty in developing countries, with its prevalence rising with age in both childhood and adulthood, regardless of gender [2, 3]. Few decades ago, obesity prevalence in Western and Westernizing countries was more than doubled, the cause of which could be attributed to over-nutrition [4]. What then is obesity? Obesity is described as the accumulation of adipose tissue to excess and to an extent that impairs both physical and psychosocial health and well-being [3]. More so, obesity presents a specific concerns and challenges for the reproductive

health of men and women, affecting fertility, reproduction, pregnancy and the resulting child's long-term health [4]. An epidemiological study by the world health organization (WHO) revealed that approximately 2 billion adults are overweight [5].

Palm trees (*Elaeis guineensis*) are native to Africa and other countries such as Malaysia and Indonesia [6]. They bear the palm fruits from which red palm oil, RPO is extracted. Despite its usefulness as an essential oil for cooking, there have been insufficient evidence and inconsistent reports on the effect of RPO in human health and wellness. The aim of this review article, therefore, is to provide an overview of the use of red palm oil in the amelioration of the negative health effects of obesity and male infertility.

2. Origin

Red palm oil (RPO), found in the tropical and sub-Saharan Africa is natural oil obtained from the fleshy red mesocarp of the fruits from the oil palm tree (*Elaeis guineensis*). RPO contains lipid-soluble antioxidants like carotenoids (α and β-carotenes, lycopenes), vitamin E (in the form of α, β, δ tocotrienols and tocopherol) and ubiquinone [7]. It has also been reported that the red-orange color of red palm fruits was due to its carotene and lycopene contents as present in tomatoes, carrots and other fruits and vegetables [7]. Red palm oil is different from other plant and animal oil because it contains 50% saturated fatty acids, 40% unsaturated fatty acids, and 10% polyunsaturated fatty acids [8–10].

3. Biological and medicinal usefulness of RPO

Studies indicate that RPO has beneficial effects on arterial thrombosis and hypertension associated with oxidative stress [11, 12] and is also protective against the consequences of ischemia/reperfusion injury [13, 14]. More so, Aboua et al. [15] showed that RPO could possibly inhibit apoptosis in rat sperm, while its role in reducing oxidative stress in HIV/AIDS and tuberculosis patients has also been reported [16]. Besides, RPO has been reported to be useful in wound healing [17]. Moreover, as palm oil is very rich in carotenes, it is also found useful for preventing and treating vitamin A deficiency [18]. Therefore, due to its antioxidant effect, RPO is recommended as a supplement to the diet of pregnant women. RPO also possesses potentials in preventing high blood pressure and breast cancer [19].

3.1 RPO in diabetes mellitus

The effects of palm oil (PO) and groundnut oil (GO) supplementation on the antioxidant status and diabetic indices in Alloxan (100 mg/kg) induced diabetic Wistar rats was investigated. In this study, blood glucose, plasma vitamin E, superoxide dismutase (SOD), total protein and albumin levels were measured. It was concluded that GO exhibited superior antioxidant activities and that the supplementation of red palm oil and ground nut oil as a source of antioxidant was beneficial in diabetic state as it reduced blood glucose and enhance antioxidant status [20]. A similar study investigated the antioxidant status in streptozotocin-induced diabetic male Wistar rats following intake of red palm oil and/or rooibos. The result revealed the anti-oxidative potentials of red palm oil, rooibos, and a synergistic effect of their combination in diabetic conditions, hence, they could be beneficial in the management of diabetes and its complications [21].

3.2 Linking metabolic syndrome, obesity and type 2 diabetes

Obesity, in excess of visceral adiposity, is closely related to insulin resistance, hyperglycemia, dyslipidemia and hypertension; taken together, these group of metabolic disorders are termed "metabolic syndrome [22]. Abdominal obesity is the key component of the metabolic syndrome, with a predominance of intra-abdominal visceral fat accumulation, indirectly measured by waist circumference in clinical practice. Research has shown that a chronic low-grade inflammation and an activation of the immune system are involved in the pathogenesis of obesity-related insulin resistance and type 2 diabetes [23]. The investigators noted that the systemic inflammatory markers are risk factors for the development of type 2 diabetes and its macrovascular complications. Besides, adipose tissue, liver, muscle and pancreas are themselves sites of inflammation when there is obesity. An infiltration of macrophages and other immune cells is observed in these tissues associated with a cell population shift from anti-inflammatory to a pro-inflammatory profile. It is noteworthy that these cells are crucial for the production of pro-inflammatory cytokines, which act in an autocrine and paracrine manner to interfere with insulin signaling in peripheral tissues or induce β-cell dysfunction and subsequent insulin deficiency. Most especially, the pro-inflammatory interleukin-1β is implicated in the pathogenesis of type 2 diabetes through the activation of the NLRP3 inflammasome.

4. Obesity

Obesity, by definition, is an excess of body fat that poses a risk to health. It is assessed clinically via the expression of body weight as a function of height – the body mass index (BMI). This is calculated by dividing an individual's weight (in kilograms) by the square of their height (in meters) (kg/m^2) [3, 24]. BMI is used in adults to delineate overall body fatness where a BMI of 18.5–24.9 kg/m^2 is considered to be normal. Abnormal BMI's are sub-categorized according to severity, where a BMI $\geq$ 25 kg/m^2 is considered to be within the overweight range, BMIs $\geq$30 kg/m^2 are considered as obesity and BMI ranges $\geq$40 kg/m^2 are classified as severe/morbid obesity. Obesity is, however, regarded as a disease of opulence, easily remedied by the reduction of food intake and considered to be irrelevant elsewhere. Furthermore, obesity was not a major concern for the WHO as their priority was to deal with malnutrition and the problems of the third world. By the mid-1990's, obesity had become a prominent problem for obesity specialists but was still not being taken seriously by most national governments. The prevalence is generally higher in women than in men, although the highest incidence was recorded in males aged 25–29 years residing in low-middle income countries.

4.1 Causes of obesity

Obesity is an unintended consequence of a 'Western lifestyle' [25] where economic, social and technological advances [26] have resulted in urbanization and reduced physical activity [27]. Diets have transitioned from natural, organic foods to refined, high fat and high sugar alternatives, leading to a nutrition transition parallel to the observed economic growth [28]. These changes have led to a rapid increase in the prevalence of obesity [25]. As a historically Western disease, obesity was largely localized to developed countries until recent decades where middle- and low income-countries began to experience rates comparable to those of high-income countries. The rapid economic expansion and modernization experienced

by middle- and low-income countries, as well as changing diets, are the greatest contributors to this epidemic [28] as more and more of these countries adopt Western diets and lifestyles. Close to 30% of the populations within middle income countries are classified as overweight or obese, with South Africa (SA) having the highest prevalence in sub-Saharan Africa, where the prevalence was reported to be 27% in adults over the age of 18 years in 2016 [29]. While the predominant causes of the energy imbalance seen in obesity are inadequate physical activity and unhealthy diets, not all those who are exposed to these unfavorable behaviors will develop the disease. Obesity arises from the interactions between an at-risk genetic profile and environmental risk factors, such as physical inactivity, excessive caloric intake, the intrauterine environment, medications, socioeconomic status, and possibly novel factors such as insufficient sleep, endocrine disruptors, and the gastrointestinal micro biome [30]. Obesity is a multifactorial disease, and many underlying factors disproportionately predispose subsets of the population to its development, and several of these are non-modifiable factors including age, gender, race, and genetics. Specific structural and functional changes are observed in obese visceral adipose tissue, together with local inflammation and adipokine production, promoting metabolic disturbances [31, 32]. Obesity leads to the presence of ectopic fat surrounding organs and to the accumulation of lipids in tissues themselves. Peripancreatic adipose tissue is implicated in glucose homeostasis regulation and can be impaired in obesity.

4.2 Prevention of obesity

Obesity is not only a clinical problem, but also a public health concern. A deeper assessment of obesity requires a multidisciplinary and transdisciplinary approach with complementary knowledge of molecular, clinical, bioinformatic, and syndemic frameworks that affect the underlying mechanisms and factors that have resulted in the current epidemic of obesity [33].

Strong evidence exists that weight loss reduces blood pressure in both overweight hypertensive and non-hypertensive individuals; reduces serum triglycerides and increases high-density lipoprotein (HDL)-cholesterol and generally produces some reduction in total serum cholesterol and low-density lipoprotein (LDL)-cholesterol [34]. A variety of effective options exist for the management of overweight and obese patients, including dietary therapy approaches such as low-calorie diets and lower-fat diets; altering physical activity patterns; behavior therapy techniques; pharmacotherapy; surgery; and combinations of these techniques. In this chapter, red palm oil is being proposed as treatment regimen for obesity prevention.

4.3 Red palm oil in obesity prevention

The oil palm tree (*Elaeis guineensis*) from the family Arecaceae is a high oil-producing agricultural crop. Palm oil is available in different forms, which include crude or red palm oil and refined palm olein (refined PO) [35]. Despite the contentious issues surrounding dietary fats, they are considered essential nutrients because they are required to perform critical functions in the body including serving as a carrier of preformed fat-soluble vitamins, enhancing the bioavailability of fat-soluble micronutrients and providing essential substrate for the synthesis of metabolically active compounds (such as the steroid hormones, testosterone, estrogen and progesterone) among other useful functions. These benefits of fats notwithstanding, diets that are high in fat are strongly associated with an increased prevalence of obesity and an increased risk of developing coronary artery disease, high blood pressure, diabetes mellitus, and certain types

of cancer [36]. RPO consumption's effects on health are still debated. Two of the most important edible oils in the sub- Saharan Africa, are coconut oil and palm oil. Along with palm kernel oil, they are often referred to collectively, as the tropical oils and are typically known to be rich in saturated fats [36]. According to Boateng and co-workers [37], RPO contains α, β and γ carotenes, phytosterols such as sitosterol, stigmasterol and campesterol. These lipophilic sterols are easily absorbed in the gastrointestinal tract, and then converted through a series of enzymatic reactions into cholesterol, which is a major precursor of steroid hormones. A moderate use of palm oil is likely to be beneficial for blood lipid profiles. The RPO rich vitamin E, composed mainly of tocopherols and tocotrienols act as potent antioxidants that make it relatively stable to oxidation. Both animal and human studies show that tocotrienols could reduce plasma cholesterol, apolipoprotein B, thromboxane B2, and platelet factor IV. They could also inhibit or delay the oxidative deterioration of cellular membranes. The benefits of RPO to health include a reduction in the risk of arterial thrombosis and/or atherosclerosis, inhibition of endogenous cholesterol biosynthesis, platelet aggregation, a reduction in oxidative stress and a reduction in blood pressure. It has also been shown that dietary red palm oil, taken in moderation in animals and humans, promotes the efficient utilization of nutrients, activates hepatic drug metabolizing enzymes, facilitates the hemoglobinization of red blood cells and improves immune function [7]. All the above-mentioned as well as hyperlipidemia and hypertension are underlining conditions that characterize obese male.

In a systematic review on animal intervention studies, Syarifah-Noratiqah et al. [38] concluded on the evidence that palm oil and palm olein possess high potential as lipid-lowering agents. In another study on pharmacological potential of Oil Palm Phenolics (OPP), Syarifah-Noratiqah et al. [39] also concluded that individual components of OPP (Caffeoylshikimic Acid (CFA), p-Hydroxybenzoic Acid, Protocatechuic Acid (PCA) and Hydroxytyrosol, have unique pharmacological potential including neuroprotection, anti-cancer, cardioprotection and hypolipidemic effects. Single or in combination of all three phenolic acids into one OPP liquor would produce high pharmacological potential OPP liquor for the nutraceutical and pharmaceutical market. OPP extracted from bio-wastes of oil palm industry would provide an opportunity to transform a biowaste burden into a range of potential applications for health and wellness.

5. Male infertility

The WHO defines infertility as 'the inability of a sexually active, non-contracepting couple to achieve pregnancy in one year [40]. According to the WHO, about 9% of couples worldwide have fertility problems and around 70 million people are regarded as infertile [41]. The male factor varies and many publications contribute a factor of 30–40% to the man, 40% to the woman and the remainder is said to be idiopathic. The production of spermatozoa (spermatogenesis) in the testis and their subsequent maturation to physiological functionality in the epididymis are complex processes that needed to be strictly controlled in a timely and spatial manner. A disturbance of any of the individual steps involved may lead to impaired male fertility.

5.1 Causes of male infertility

There are many internal and external causes that can lead to male infertility. They span from genetic mutations or variations, medical conditions to lifestyle choices. Genetic mutations may distort e.g., hormonal levels of Follicle Stimulating

Hormone (FSH), Luteinizing Hormone (LH) or testosterone or their correspondent receptor sensitivities whereas genetic variations in the number of sex chromosomes can lead to clinical syndromes such as Turner (X0) or Klinefelter (XXY). Medical conditions cover a wide range and include distorted hormonal levels of the hypothalamic–pituitary-testicular (HPT) axis, immunological infertility (production of sperm antibodies), obstruction of the ductus deference, retrograde ejaculation (i.e. ejaculation into the bladder), erectile disfunction, varicoceles (swollen veins in the scrotum that block blood drainage), sperm disorders (mostly very low numbers or not made at all, odd shape, no straight motility, not fully mature thus unable to fertilize the female egg). External factors may involve exposure to toxicants (such as pesticides, heavy metals, PCB etc.) [42], heat [43], radiation [44] or xenoestrogens etc. [45]. Lifestyle choices potentially leading to male infertility may embrace excessive alcohol, illicit drugs or medication abuse. Furthermore, medical comorbidities such as cystic fibrosis, chronic obstructive pulmonary disease, and obesity can lead to male infertility [41].

The group of medical conditions including dyslipidemia, hypertension, insulin resistance, and obesity is often referred to as 'metabolic syndrome' (MetS) [46]. Each of these disorders can affect male fertility in its own way but when combined as in metabolic syndrome, additive effects have been observed [46]. Lotti et al. [47] noticed a decline in age-adjusted testosterone levels in male MetS patients without changes in LH and FSH levels. Furthermore, after adjusting for age and total testosterone, a negative correlation between the number of MetS components and normal spermatozoa morphology as well as erectile dysfunction was found [47]. In infertile men, a positive correlation between MetS and prostatic abnormalities has been shown [48]. Sertoli cells of the testis use glucose to produce lactate that is needed by the developing germ cells [49]. The transport of glucose from the blood capillaries through the basal compartment of the Sertoli cells and then through the blood-testis barrier towards the adluminal compartment of the seminiferous tubules is tightly controlled. Furthermore, this glucose transport is also regulated by the Hypothalamic–Pituitary-Gonadal (HPG) axis [50]. Hyperglycemia conditions in testicular cells such as in diabetic men interfere with these transport mechanisms and may thus compromise spermatogenesis. For males, obesity has a severe impact on the development and function of the testicles, epididymis, prostate, and other male reproductive organs [51]. With the increase of body mass index and abdominal circumference, ejaculation volume gradually reduces, and the total sperm count in semen also decreases [52]. In addition, obesity damages sperm chromatin or inhibits chromatin condensation [43]. In men, obesity may cause a gradual decline in sperm quality and thus reduce fertility [53]. Obesity also led to DNA fragmentation, increases apoptosis and epigenetic changes that can be transferred to the offspring [54].

5.2 Prevention and treatment

A healthy diet and lifestyle combined with regular physical activity can help to avoid MetS and obesity and thus may prevent male infertility. Spermatozoa are very susceptible to oxidative stress. Because of their small amount of cytoplasm, spermatozoa have very limited capacity to defend reactive oxygen species. Moreover, the plasma membrane of spermatozoa contains a high amount of unsaturated fatty acids which makes them an easy target for ROS-induced damages such as lipid peroxidation and DNA damage. Both can lead to reduced semen quality and thus affect male fertility. Food that is rich in anti-oxidants, vitamins (A, E and C) and omega-3 fatty acids such as many plant products, fish and other seafood has been shown to be beneficial for male fertility [55, 56]. The high provitamin A content of RPO may

be beneficial for fertility because vitamin A plays a role in spermatogenesis [57]. RPO also contains vitamin D which is a known regulator of enzymes involved in the production of steroids (steroidogenesis) [58].

5.3 Red palm oil in male infertility prevention

As shown in the previous section in this chapter, RPO is rich in antioxidants such as carotenoids, vitamin E derivatives, and ubiquinone and should thus be a good candidate to prevent male infertility. Though, scientific literature on the effect of RPO on male reproduction is scarce.

Overall, a direct effect of RPO on spermatogenesis is inconclusive. Some in vivo studies reported poor sperm functions and morphology after exposure to RPO, whereas other noticed no significant effects. However, many studies demonstrated that RPO can protect against or ameliorate toxin- or medical condition-induced male infertility. Aboua et al. [59] showed that long-term RPO supplementation to rats had no effect on enzymes activities or substrates involved in the antioxidant defense system (GSH, CAT, SOD), lipid peroxidation or intracellular ROS levels in spermatozoa. Similarly, RPO exposure did not significantly change concentration or motility of spermatozoa. RPO did, however, significantly lower or even prevent ROS-induced changes to peroxide-injected animals. Peroxide alone led to lipid membrane peroxidation and higher intracellular ROS levels and consequently significantly lowered sperm concentration and motility and reduced enzyme activities. But peroxide exposure in combination with RPO prevented these changes and thus protected the sperm from ROS-induced damage [59]. In a similar approach Jegede et al. [60] demonstrated that RPO can attenuate heavy metal induced testicular damage in rats. Here, the administration of lead acetate led to a significant rise in reactive oxygen species that in turn decreased GSH concentrations and led to reduced spermatozoa numbers and motility and an increase in abnormal sperm morphology. Coadministration of RPO was able to partially protect against these changes as shown by significantly increased GSH levels and improved spermatozoa parameters. Peroxide in higher concentration induces DNA breaks and programmed cell death (apoptosis) in spermatozoa which consequently leads to lower sperm counts and reduces male fertility [61]. Aboua et al. [15] demonstrated that a 60-day oral supplementation of RPO can prevent peroxide-induced apoptosis in rat spermatozoa. Here, RPO supplementation prevented the activation of caspases 3 and 7 and, therefore, apoptosis. In addition, RPO seems to reduce the activation of p53 which will also lessen apoptosis.

As stated before, obesity can lead to diabetes type 2 which is known to impair male fertility by inter alia reducing sperm quality [53]. In diabetic rats RPO supplementation was shown to elevate the percentage of progressive motile spermatozoa [9]. The authors further demonstrated that RPO in combination with an aqueous extract from fermented rooibos exerted no negative effect on sperm motility parameters as measured by Computer Assisted Sperm Analysis but improved these parameters in diabetic rats. There is a significant linear relationship between abdominal obesity and prostate cancer [62]. Treatment of prostate cancer often involves radiation therapy or surgery that will remove the prostate and the seminal vesicles. Both options greatly impair the production of semen and thus often led to male infertility. RPO can lower the unpleasant effects of chemotherapy and is thus used in cancer management [63]. However, RPO or more precisely, a tocotrienol-rich fraction (TRF) from RPO may have potential as a remedy for prostate cancer. Using three different prostate cancer cell lines [64] noticed that TRF selectively inhibited cell proliferation and induced apoptosis in these cells.

As shown above, the antioxidative capacity of RPO can help to reduce or even prevent ROS-induced damage to the male germ cell. On the other hand, a certain physiological amount of ROS activity is essential for spermatogenesis and normal sperm functions. Thus, excessive use of antioxidants can have a negative effect on spermatogenesis and male fertility [65, 66]. This might be the reason as to why Aboua et al. [67] noted a significant decline in the motility of spermatozoa in vitro after exposure to RPO. A more recent in vivo study investigated the effects of a specific high-fat diet on the male rat reproductive performances. Male Wistar rats were fed either with a 15% palm oil diet or a standard diet for 16 weeks. The authors concluded that the palm oil significantly impaired sexual behavior, ejaculatory activities and sperm motility, viability, and morphology of male rats [68]. Overall, a precisely tuned balance between ROS level needed for physiological sperm function and sufficient antioxidants to combat oxidative cellular damage is vital for male fertility.

6. Conclusion

Obesity is a worldwide occurring problem that causes many medical disorders and diseases. Obesity is known to disrupt male fertility and the capacity to impair reproduction through alteration in the hypothalamic- pituitary-gonadal axis. The obesity induced disruption of testicular steroidogenesis and metabolic dysregulation, cytokines and adipokines negatively impact on semen parameters such as sperm concentration, motility, viability, and normal morphology. In addition, obesity inhibits chromatin condensation, DNA fragmentation, increases apoptosis and epigenetic changes that can be transferred to the offspring. A balanced diet and healthy lifestyle combined with regular physical activity can help to avoid metabolic syndrome and obesity and thus, may prevent obesity-induced male infertility. Spermatozoa are extremely sensitive towards oxidative stress. Therefore, a sensible daily supplementation of normal diet with an antioxidant-rich natural product such as RPO might be useful to protect spermatozoa from oxidative stress and helps to preserve male fertility.

7. Future research

No doubt, RPO should be considered as one of the healthy and nutritional oils. However, there are inconsistent and controversial reports on its role in amelioration of obesity and by extension, male infertility prevention. Therefore, further studies to investigate the effect of RPO on the renal, hepatic, and cardiac functions as well as spermatogenesis in dietary-induced obese male Wistar rats are hereby proposed. Besides, human volunteers can be recruited for a longitudinal testing on the effect of the oil consumption over a period of 6–12 weeks.

Conflict of interest

The authors declared no conflict of interests.

DOI: http://dx.doi.org/10.5772/intechopen.98393

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