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Effects of long-term feeding of the Obudu natural honey and table sugar-sweetened diets on sex hormones of male and female albino Wistar rats

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ABSTRACT

Aim: This study was done to assess the impact of long-term consumption of table sugar and natural honey on the sex hormones and the biochemical implication of this differential effect.

Materials and Methods: Fifty male and female rats (25 rats per sex) weighing 100–120 g were used for the experiment. They were housed in standard laboratory cages at room temperature (25°C), humidity of 50%–64%, and maintained on a 12:12 hour light/dark cycle in the animal house. After a 29-week period of feeding of equivalent quantities of natural honey and table sugar separately, body weight and plasma hormones were quantified in them. The diets were formulated to simulate average sugar composition of common sweetened foods and beverages.

Results: The growth pattern observed showed that the diets significantly induced a gain in body weight with alteration of the serum levels of sex hormones. In the females, sugar-sweetened diets inhibited follicle stimulating hormone (FSH) and luteinizing hormone (LH) secretion at high dose but increased the levels of progesterone and estradiol while the consumption of honey-based diets inhibited progesterone and estradiol secretion but stimulated testosterone secretion at a low percentage. In female animals fed with high sugar concentration diet, the serum levels of LH and FSH were observed to be decreased with a decrease in the level of testosterone and an increase in estradiol level. The level of estradiol was found to be significantly higher in sugar-fed animals than the honey-fed groups in the females ($p < 0.05$). In the male, intake of the sugar-based diet increased the levels of LH, FSH, and testosterone and the consumption of honey at high concentration stimulated FSH and LH secretion while honey at low concentration stimulated testosterone secretion.

Conclusion: This study has shown that excess and extended intake of table sugar alters the relationship between gonadotropins (LH, FSH), oestradiol, and testosterone in the female rats more than the Obudu natural honey. This exerts adverse effects on the reproductive function which is graver in females than the males.

ARTICLE HISTORY

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KEYWORDS

Honey; follicle stimulating hormone (FSH); luteinizing hormone (LH); testosterone; estradiol; sex hormones; sugar

Introduction

In contemporary times, honey has been used for a number of purposes: nutritional, medicinal, industrial, and commercial purposes [1]. Its use is linked to its high energy carbohydrate food value, antibacterial activity, and granulation value [2]. Natural honey has been recognized as the most traditional sweetener for mankind [3]. Most times the honey is consumed as an energy meal. Natural honey is a supersaturated hygroscopic solution and its principal chemical components are carbohydrates comprising majorly of a mixture of sugar making up about 95% of the dry weight of honey [4,5]. The main carbohydrates in honey are glucose and fructose. Other forms of sugars include panose, erlose, isopanose, centose, and gentiobiose, which are present in very minute quantities [5]. Similarly, consumption of sugar-sweetened diets has increased in many developing countries as a result of rising rates of urbanization and globalization [6]. Income

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rise and technological advancement come with a drastic change to the western dietary lifestyle i.e., diets rich in simple sugars are gradually replacing traditional diets that are high in complex carbohydrates and fiber [7]. Both natural honey and table sugar are calorie-dense sweeteners. Both are composed of fructose and glucose; but while fructose and glucose are bound together in table sugar to form a complex called sucrose, they appear in simple forms in natural honey and are easily absorbed [8]. A tablespoon of white granulated sugar contains 49 calories while a tablespoon of honey has 68 calories, suggesting that honey has higher calories than the sugar when consumed in equal amounts [8]. Consumption of table sugar in diets and beverages is believed to result in weight gain and associated diseases, such as diabetes, polycystic ovaries, infertility, and cancer of the uterus in overweight females, as opposed to natural honey which is rather believed to be nutritionally beneficial. The result is that natural honey becomes naturally preferred, hence consumed in large quantities, which tend towards abuse by those who can afford it. Honey is sweeter than table sugar; hence, it is required in relatively smaller quantity than table sugar. Honey is said to have a lower glycemic index (GI), an average of 55 ± 5 while table sugar has a GI of 68 ± 5; hence, natural honey has a lower effect on increasing blood glucose level and therefore, could be a better alternative sweetener than the table sugar for the diabetics [8].

Excess sugars (particularly glucose) in the body are converted to glycogen and fat for storage as triacylglycerols in the adipose tissue, leading to weight gain [9–11]. Uncontrolled weight gain results in obesity and other health conditions, such as cardiovascular diseases, hyperlipidemia, hypertension, diabetes, reduction in reproductive capacity, increased dental diseases, and certain cancers [12–14]. The resulting disease conditions contribute immensely to morbidity and mortality. Globally, obesity which results from over-nutrition has reached epidemic proportions [7]. Thus, increased free sugar intake poses a threat to the quality of nutrients in a diet because it provides a higher amount of energy with no specific nutrient, and leading to an increased tendency to obesity with its attendant complications. Extremes of nutritional imbalance (both under-nutrition and obesity) in men lead to marked hypogonadotropic hypogonadism, with a resultant severe decrease in testosterone and luteinizing hormone concentrations [15]. Malnutrition, under-nutrition, and severe obesity can also cause a disruption of the menstrual cycle in the females. There is a relationship between a high follicular oestradiol level and sweetened soda consumption among premenopausal women [16]. Obesity at an early age predisposes to the development of menstrual irregularities and infertility as well as increased risk of miscarriages in women. Likewise, high frequency of erectile dysfunction and decreased sperm production in men with high body mass index has been reported [17].

Fructose and glucose are broken down in the hepatic region, with the excess converted and stored as lipids (triacylglycerol). An increase in the synthesis of lipids deactivates sex hormone binding globulin (SHBG) gene, leading to a reduction in the levels of SHBG protein in circulation. It is this protein that controls the level of testosterone and estrogen in the blood. Abnormal levels of SHBG distort the delicate balance between estrogen and testosterone [18]. According to Nervey et al. [19], excessive consumption of honey appears to have a deleterious effect on serum levels of testosterone but enhances the production of follicle stimulating hormone (FSH), luteinizing hormone (LH), and prostate-specific antigen. A reduction in serum testosterone levels could lead to low sex drive, changes in mood, loss of muscle strength, and increased body fat [20]. Chronic consumption of natural honey and sweetened foods has been linked to alteration in plasma levels of many hormones. This study assesses the effects of chronic consumption of both honey and sweetened foods on the plasma levels of sex hormones of both male and female Wistar rats.

Materials and Methods

Materials

Natural honey was obtained from the Obudu Cattle Ranch, Obanliku L.G.A, Cross River State, Nigeria, whereas white granulated sugar was purchased from Golden Sugar Company (Apapa, Lagos state). Glucose sensor meter with its corresponding test strips (Accu-Chek Active) was procured from Mannheim, Germany. Glucose was validated before use, and standard operative procedures were followed in its use.

Animals

Fifty male and female rats (25 rats per sex) weighing 100–120 g were used for the study. They were housed in standard laboratory cages at room temperature (25°C), humidity of 50%–64%, and

maintained on a 12:12 hour light/dark cycle in the animal house. The animals were allowed to acclimatize to the environmental conditions and the pelletized feed for 4 weeks before the commencement of the experimental feeding procedures. All experimental procedures were carried out in line with the University of Calabar and the International Animal Care guideline.

Diets formulation and feeding of experimental animals

A day prior to the commencement of dietary manipulations, the animals fasted overnight and their body weights and fasting plasma glucose (FPG) were measured the next morning. Thereafter, the animals were randomly assigned to 10 groups of 5 consisting of equal number of both sexes (i.e., five rats per sex), however, the males were kept separate from the female rats, each with a similar average weight per group at the onset of the experiment. The diets were formulated to simulate average sugar composition of common sweetened foods and beverages. The percentages of the sweeteners equilibrated gravimetrically. Fresh diets for each group were compounded every other day to avoid spoilage. The animals were allowed access to the diets and drinking water ad-libitum. The leftover and spilled diets were carefully collected and weighed in order to determine the animals' diet intake i.e., the difference between the initial diet supplied and the leftover. Diet intake, body weight, and fasting blood glucose were measured every other day throughout the 29-week feeding duration. FPG was measured using the glucose oxidase method. At the end of 29-week treatment, the last *in vivo* measurements were conducted and the rats, having been fasted overnight (but had free access to water), were anesthetized using chloroform vapor. Sterile syringes and needles were used to collect whole blood from the animals by cardiac puncture. The blood was emptied into non-heparinized tubes, allowed to stand for 2 hours, and then centrifuged for 10 minutes at 3,000 revolutions per minute (rpm). The rats were aged 2 and 8 months at the time of feeding commencement and at the time of sacrifice, respectively.

Serum biochemical analyses

Serum was carefully aspirated into sample tubes and stored frozen until used for biochemical analyses. Serum level of hormones was determined using rat assay kits of testosterone (T), estradiol (E), progesterone (P), FSH, and LH. These were determined in serum by appropriate methods using commercial assay kits based on the principle of enzyme linked immunosorbent assay (Marburg, Germany) [21]. The assay procedures used were as contained in the kit manuals. Using appropriate wavelengths for each analyte, the optical density was taken and read with a microtiter plate reader, after which the corresponding concentration was calculated.

Statistical analysis

All data were expressed as mean ± standard error of mean (SEM). The SPSS software (version 20) was used to analyze the data obtained in this study. The one-way analysis of variance was used followed by the least significant difference *post-hoc* comparison of means. Differences at $p \leq 0.05$ were considered statistically significant.

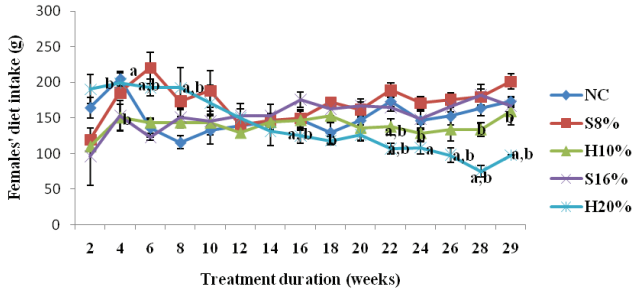
Results

Dietary intake

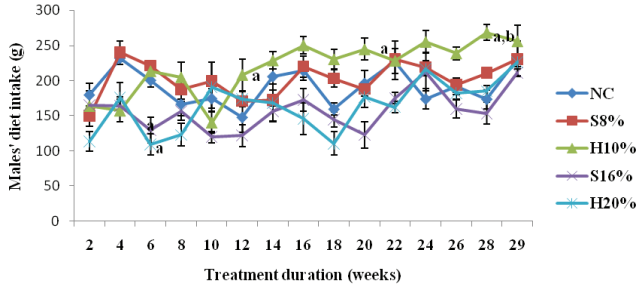
The dietary intake (in grams) of the female rats which were monitored during the course of treatment showed that in week 6, S-8% group consumed significant quantities of diets than the normal control (NC) and H-10% groups, this pattern was sustained till week 29 ($p < 0.05$). The female H-20% group ate more diets than groups NC and S-16% from week 6 to 8 at $p < 0.05$, thereafter, the rate of consumption in H-20% group declined steadily such that from week 16 till the end of administration this group ate significantly less diets than NC and S-16% groups (Fig. 1a). Overall, amongst the female rats, it was observed that for the most part of the study, dietary intake was higher in group S-8% than in any other group whereas group H-20% ate the least amount of diets. However, within their male counterpart groups, H-10% group ate the largest amount of diets than any other group in general comparison for a long period during the study as illustrated in Figure 1b, whereas the feeding pattern among the other four groups (i.e., NC, S-8%, S-16%, and H-20%) was not significantly different. Additionally, in week 6, the NC group ingested more diets than both groups S-16% and H-20% in the male category ($p < 0.05$).

Changes in body weights

According to Figure 2a, the body weights (%) in female group H-20% were significantly increased compared to the control and S-16% groups from week 2 up to week 29 of the treatment period ($p < 0.05$). A similar trend was between female groups

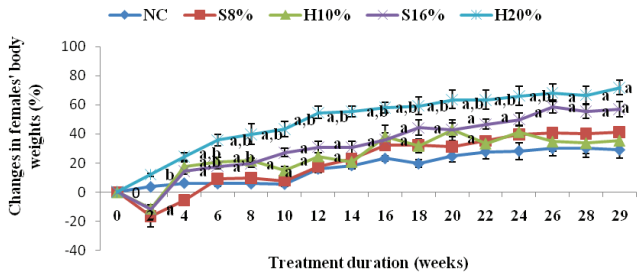


1a

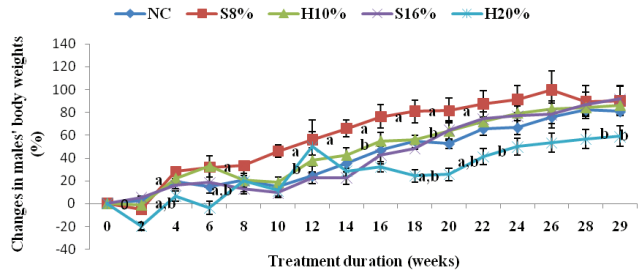


1b

Figure 1. (a and b) Diet intake (g) of the female and male rats fed with natural honey and table sugar-sweetened diets, respectively. NC = normal control, S-8% = 8% sugar-sweetened diet group, S-16% = 16% sugar-sweetened diet group, H-10% = 10% honey sweetened diet group, and H-20% = 20% honey sweetened diet group. a = $p < 0.05$ *vs.* NC and b = $p < 0.05$ *vs.* corresponding energy group. Values represent the means ± SEM, $n = 5$.



2a



2b

Figure 2. (a and b) Changes in body weights (%) of female and male rats fed with natural honey and table sugar-sweetened diets, respectively. NC = normal control, S-8% = 8% sugar-sweetened diet group, S-16% = 16% sugar-sweetened diet group, H-10% = 10% honey sweetened diet group, and H-20% = 20% honey sweetened diet group. a = $p < 0.05$ *vs.* NC and b = $p < 0.05$ *vs.* corresponding energy group. Values represent the means ± SEM, $n = 5$.

S-16% and NC within the aforementioned duration, whereas the weights of H-10% rats increased considerably relative to NC rats (weeks 4–20) and S-8% rats (weeks 4–8) ($p < 0.05$). Generally, with respect to the females, group H-20% had the highest body weight while the control had the lowest weight throughout the experimental duration. However, the male rats demonstrated results different from the females in terms of their body weights in that, broadly, the highest and lowest body weights were displayed by groups S-8% and H-20%, this pattern was sustained during the entire treatment time. Figure 2b details a significant increase in the body weights of male S-8% group compared to groups NC and H-10% (weeks 2–20) ($p < 0.05$).

Relative weights of total white adipose tissue and testes

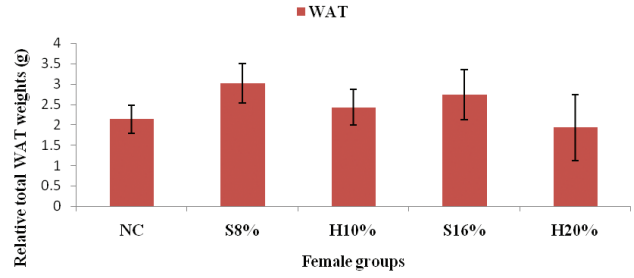
There was no significant difference in the relative weights (g) of total white adipose tissue (WAT) among the female groups ($p > 0.05$) as depicted in Figure 3a, the WAT comprised of perirenal and epididymal WAT. In contrast, data obtained revealed that the relative weights of total WAT in the male honey-fed and sugar-fed groups (i.e., H-10% and S-16%) were significantly greater than in the NC group at $p < 0.05$ (Fig. 3b). However, unlike the situation with the male rats' WAT, relative weights (g) of the male rats' testes showed no significant difference between the control and treated groups ($p > 0.05$) (see Fig. 3b).

Plasma hormone concentration

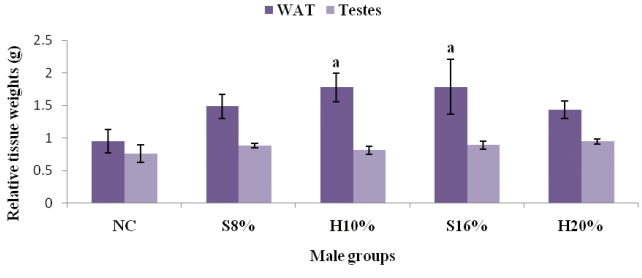
The concentration (mIU/ml) of LH in the sera of female rats treated with sugar-sweetened diet (S-16% group) were significantly reduced relative to the control group at $P < 0.05$ (Fig. 4a). Likewise, concentrations of sera LH in the male rats were detected to have increased in the S-16% group compared to the control and their honey-fed counterparts (H-20% group) ($p < 0.05$) as demonstrated in Figure 4b.

Serum follicle stimulating hormone

In Figure 5a, there was a significant decrease in FSH concentrations in the sugar-fed group (S-16%)

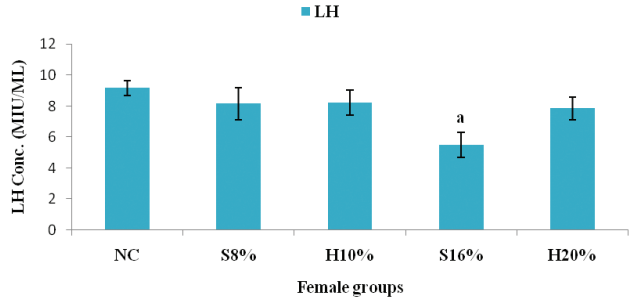


3a

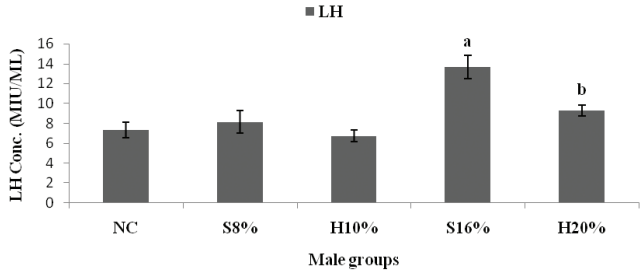


3b

Figure 3. (a and b) Relative weights (g) of total WAT and testes in female and male rats administered with natural honey and table sugar-sweetened diets, respectively. WAT = white adipose tissues, NC = normal control, S-8% = 8% sugar-sweetened diet group, S-16% = 16% sugar sweetened diet group, H-10% = 10% honey sweetened diet group, and H-20% = 20% honey sweetened diet group. a = $p < 0.05$ *vs*. NC. Values represent the means ± SEM, $n = 5$.



4a



4b

Figure 4. (a and b) Serum LH concentrations (mIU/mLl) in female and male rats fed natural honey and table sugar-sweetened diets, respectively. NC = normal control, S-8% = 8% sugar-sweetened diet group, S-16% = 16% sugar-sweetened diet group, H-10% = 10% honey sweetened diet group, and H-20% = 20% honey sweetened diet group. a = $p < 0.05$ *vs*. NC and b = $p < 0.05$ *vs*. corresponding energy group. Values represent the means ± SEM, $n = 5$.

relative to the honey-fed (H-20%) and control groups at $p < 0.05$. The reverse outcome was detected in the males, in that the FSH levels were significantly raised in the sugar-fed animals (S-8%) compared to their equivalent honey-fed animals (H-10%) at $p < 0.05$. Furthermore, FSH concentrations in the male groups of S-8%, S-16%, and H-20% were increased considerably than in the NC group ($P < 0.05$) as depicted in Figure 5b.

Estradiol concentrations in serum

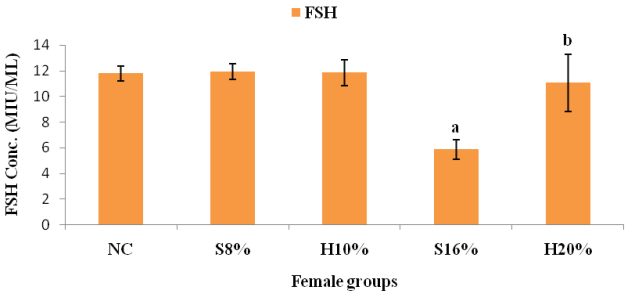
The serum concentrations (pg/ml) of estradiol in both sugar-administered groups (S-8% and S-16%) increased significantly than in the control ($p < 0.05$) unlike the honey-administered group (H-10%) whose levels decreased considerably than the normal control in the female rats (Fig. 6a). Furthermore, analyses of the female test groups indicated that the concentrations of estradiol in both sugar-fed groups were comparatively higher than those in their respective equivalent honey-fed groups at $p < 0.05$ i.e., S-8% *vs*. H-10% and S-16% *vs*. H-20%. However, neither sugar nor honey impacted on the serum estradiol concentrations in the male rats at $p > 0.05$.

Progesterone concentration

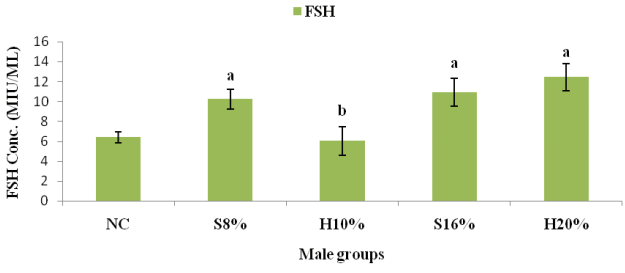
There was an observable significant reduction in the progesterone concentrations (ng/ml) of the females' honey-fed groups relative to the NC $p < 0.05$ (see Fig. 7a). Nevertheless, the sugar-fed groups (viz. S-8% and S-16%) showed higher levels of progesterone than their corresponding honey-fed groups (viz. H-10% and H-20%) in the female animals ($p < 0.05$). In the male category, there was the null effect of honey and sugar-sweetened diets on the progesterone concentrations in their sera ($p > 0.05$) and this is presented in Figure 7b.

Concentrations of testosterone

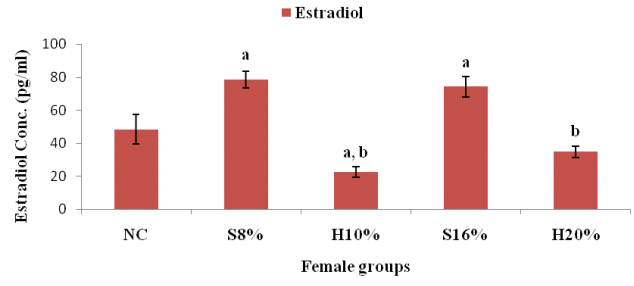
In the female rats, the only detectable significant difference was between honey-fed group (H-10%) and NC, in this case, the serum testosterone



5a



5b



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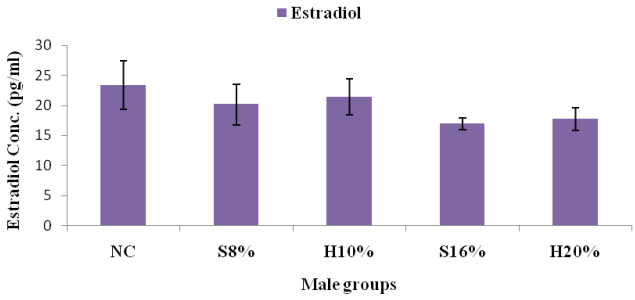


6b

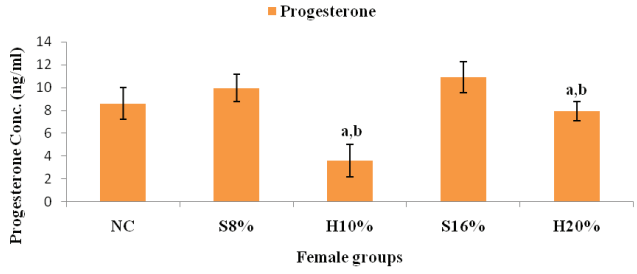
Figure 5. (a and b) Serum FSH concentrations (mIU/mLl) in female and male rats fed natural honey and table sugar-sweetened diets, respectively. NC = normal control, S-8% = 8% sugar-sweetened diet group, S-16% = 16% sugar-sweetened diet group, H-10% = 10% honey sweetened diet group, and H-20% = 20% honey sweetened diet group. a = $p < 0.05$ *vs*. NC and b = $p < 0.05$ *vs*. corresponding energy group. Values represent the means ± SEM, $n = 5$.

Figure 6. (a and b) Estradiol serum concentrations (pg/ml) in female and male rats fed natural honey and table sugar-sweetened diets, respectively. NC = normal control, S-8% = 8% sugar-sweetened diet group, S-16% = 16% sugar-sweetened diet group, H-10% = 10% honey sweetened diet group, and H-20% = 20% honey sweetened diet group. Values represent the means ± SEM, $n = 5$.

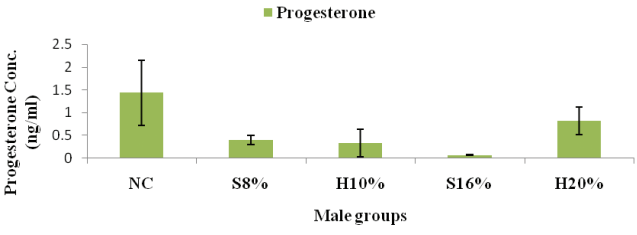
concentrations (ng/ml) in the H-10% group was raised significantly than in the NC group ($p < 0.05$) as depicted in Figure 8a. Similarly, upon analyses, the male groups H-10% and S-16% serum testosterone concentrations were elevated significantly relative to NC at $p < 0.05$. In addition, these hormone levels were markedly reduced ($p < 0.05$) in sugar-administered rats (i.e., S-8%) than in the corresponding honey-administered rats (H-10%) and this is clearly elaborated in Figure 8b.

Discussion

This study investigated and compared the effect of 29-week feeding of the equivalent of table sugar and natural honey on the sex hormones of male and female albino rats. There was a sequential progressive gain in body weight across the study groups. In the females, the progressive weight gain was observed to be significantly increased in the H-20% fed group when compared with the NC and the S-16% diet fed group, all through the treatment duration. Percentage changes in the body weight were higher in the two higher concentration groups (H-20% and S-16%) in the females; the only difference was that the increase in the body weight was consistently higher in the H-20% as compared to S-16% all through the period. H-20% diet-fed rats had the highest body weight gain and NC the lowest. The changes in body weight were found to correlate with the feed intake: the H-10% consumed the highest amount of feed, followed by the S-8% and the H-20% has the lowest dietary intake. This observation is in line with the findings of Ajibola et al. [22], that low concentration diet groups consume more feed than the higher concentration groups. Ajibola et al. [23] also stated that the growth pattern observed showed that the diets significantly induced a gain in body weight, buttressing the difference in growth pattern among the groups, with the male having a higher weight gain than the female, irrespective of their similar weight at birth, exposure to the same experimental condition and dietary treatment. Also, this study is not entirely in agreement with Ajibola et al. [23] and Anyakudo et al. [24], who argued that honey-based diet brings

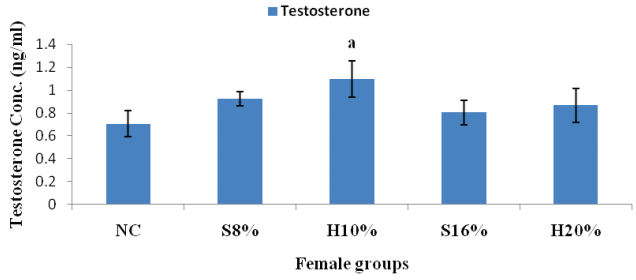


7a



7b

Figure 7. (a and b) Serum progesterone concentrations (ng/ml) in female and male rats fed natural honey and table sugar-sweetened diets, respectively. NC = normal control, S-8% = 8% sugar-sweetened diet group, S-16% = 16% sugar-sweetened diet group, H-10% = 10% honey sweetened diet group, and H-20% = 20% honey sweetened diet group. Values represent the means ± SEM, n = 5.



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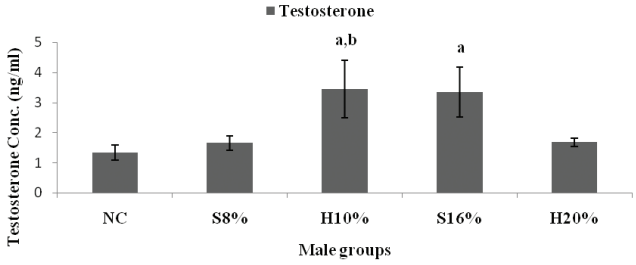

8b

Figure 8. (a and b) Serum testosterone concentrations (ng/ml) of female and male rats fed with natural honey and table sugar-sweetened diets, respectively. NC = normal control, S-8% = 8% sugar-sweetened diet group, S-16% = 16% sugar-sweetened diet group, H-10% = 10% honey sweetened diet group, and H-20% = 20% honey sweetened diet group. a = $p < 0.05$ *vs*. NC and b = $p < 0.05$ *vs*. Corresponding energy group. Values represent the means ± SEM, n = 5.

about a significant reduction in weight gain in both healthy and diabetic rats with the same daily caloric serving and insignificant increase in feed consumption of the honey fed; adding that antioxidant content of honey might be a contributing factor for reduction in weight gain .

In this study, a significant reduction in serum concentration of LH in the S-16% group of females was observed, a significant increase in the males compared with the NC. Luteinizing hormone, in conjunction with FSH, regulates the ovarian secretion of estradiol and progesterone in the females, and also, stimulates the synthesis of testosterone by the thecal cells of the ovaries and interstitial cells of the testicles. The observed significant decrease in LH concentration in the S-16% group in the female could be due to a feedback effect of estradiol or testosterone on LH secretion.

Furthermore, FSH stimulates and sustains the growth and development of the ovarian follicles in the females and the production of sperm in men. Its secretion is regulated by gonadotropin releasinhg hormone, estrogens, activine, and inhibin. It was observed that the serum level of FSH was significantly decreased in S-16%, in females, but a significant increase in the males compared with the NC. This is at variance with observations of Nervey et al. [19] of a significant increase in FSH level in the low honey concentration diet group and a significant decrease in high honey concentration fed male rats. There was also a non-significant increase of progesterone level in the sugar diet fed groups and a statistically significant decrease in honey diet fed groups in the female when compared with the control while in the male there was a null effect, this could be because progesterone is predominantly a female hormone as studied by Abdul-Ghani [25]. Nervey et al. [19] and Mosavat et al. [26] reported that honey causes a significant rise in the serum concentrations of progesterone in male and female rats fed for 10 and 8 weeks, respectively. It could be that consumption of sugar diets enhances the secretion of progesterone while honey diet inhibits its secretion in the females, this may depend on the phase of the menstrual cycle of the animals at the time. According to Al-asmakh [27], the plasma concentration of progesterone rises to peak during the luteal phase of the menstrual

cycle but decreases markedly during the follicular phase. Estradiol (E) regulates gonadotropin secretion in the ovarian cycle of the females and has a negative feedback inhibitory effect on testosterone synthesis by the Leydig cells. Estradiol also has a negative feedback on the LH secretion. The levels of E were found to be significantly higher in sugar-fed animals than the NC and the honey fed groups in the females, which agrees with the earlier submission by Mosavat et al. [26] of the low level of E in rats on honey supplements while in the male there were no significance differences. Furthermore, testosterone functions as a precursor for estrogen production, the production of testosterone is regulated by the negative feedback action of circulating testosterone on LH secretion. A high concentration of circulating testosterone will lead to a decrease in the frequency and rate of pulsatile LH released; it also enhances the development of secondary sex characteristics and control gonadotropins secretion. In this study, there was a significance increase in *T* level of female rats fed H-10% diet compared with the NC and other treatment group, this is in agreement with Nervey et al. [19] that showed a significant rise in serum concentration of testosterone and FSH in rat administered low concentration of honey. This could be because excess sugar is converted to lipid in the liver, and cholesterol, a precursor of steroid hormones is synthesized from lipids [18,28].

In the female animals fed with high sugar concentration diet, the serum levels of LH and FSH were observed to be decreased, with a decrease in the level of testosterone and an increase in estradiol level. This could be as a result of an increase in aromatase activity while the elevated level of testosterone and a decline in estradiol seen in low honey concentration could as a result of a decrease in aromatase activity. In the males, levels of both FSH and LH were observed to be elevated in high sugar concentrations (S-16%), with an increase in the level of testosterone, which could be because sugar at a high dose and long duration may cause a failure in the feedback regulation of gonadotropin by testosterone. This is because when the level of *T* is high, it regulates the rate at which LH is secreted.

Overall data obtained in this study have shown that 29 weeks feeding of equivalent quantities of natural honey and table sugar separately altered the serum levels of sex hormones; in the females sugar-sweetened diets inhibits FSH & LH secretion at high dose but increases the levels of progesterone and E and consumption of honey-based diets inhibits progesterone and E secretion but stimulated testosterone secretion at low percentage, indicating that intake of sugar-based diet might have increased aromatization activity thus leading to increased E synthesis or that excessive sugar intake may have inhibited the secretion of SHBG, which resulted in reduction in serum level of gonadotropin [18]. In the male intake of sugar-based diet increased the levels of LH, FSH, and T and consumption of honey at high concentration stimulated FSH and LH secretion while honey at low concentration stimulates testosterone secretion, this effect of low honey concentration on testosterone could be as a result of negative feedback of high testosterone level on LH and FSH, that results in a decrease in the level of circulating LH and FSH. Intake of sugar and low dose honey could enhance sperm production, although an increase in testosterone was actually supposed to bring about a reduction in the level of FSH and LH, therefore, sugar intake may also have inhibited the secretion of SHBG which may have been the cause of elevated level of testosterone [18].

A study in mice and humans indicates that the genes involved in the regulation of the concentration of functional estrogen and testosterone in the body can be inhibited by excess glucose and fructose [18]. In women, an elevated amount of testosterone is associated with metabolic impairments [29].

Conclusion

This study has shown that excess and extended intake of table sugar alters the relationship between gonadotropins, estradiol, and testosterone in the female rats. Long-term consumption of a relatively high amount of table sugar may exert an adverse effect on the reproductive function more than the Obudu natural honey. The potential adverse effect of long-term consumption of table sugar may be graver in females than the males. Further investigation is required to establish these findings.

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