**Modulating serum biochemistry, lipid profile, and antioxidants defense in Rabbit Bucks with dried date palm fruit (*Phoenix* *dactylifera*) meal supplementation**

**Abstract**

*The aim of this study was to investigate the effects of dietary supplementation with dried date palm fruit meal (DDFM) on serum biochemistry, lipid profile, and antioxidant defense mechanisms in rabbit bucks. A total of thirty-six (36) male rabbits between the age of 8–10 weeks were used for the study. The rabbits were randomly allocated to the to four dietary treatments in a completely randomized design designated as T1 (0.00% DDFM, control), T2 (0.50% DDFM), T3 (1.00% DDFM), and T4 (1.50% DDFM) in a 168-day (24 weeks) study. Each treatment was further replicated three time to have three rabbit per replicate. At the end of the feeding trial, blood samples were collected from the ear vein for biochemical, lipid profile and serum antioxidant examinations. The data obtained were analyzed in a one-way analysis of variance (ANOVA) using SPSS version 20. The Serum biochemical analysis indicated significant reductions (p < 0.05) in total protein, albumin, urea, and alanine aminotransferase (ALT) levels with increasing DDFM supplementation, while aspartate aminotransferase (AST) and globulin levels exhibited a dose-dependent increase. The mean globulin was higher (p<0.05) in bucks fed T3 diet, with a mean value of 34.00 g/dL than in those fed T1, T2, and T4 respectively, which all had similar statistical values of 26.50, 23.00, and 22.50 g/dL respectively. Lipid profile analysis revealed significant (p < 0.05) alterations, with elevated triglycerides and total cholesterol at 1.50% and 1.00% DDFM inclusion, respectively, while high-density lipoprotein (HDL) levels remained unaffected. Antioxidant enzyme activities, including superoxide dismutase (SOD), glutathione (GSH), and catalase (CAT), increased significantly (p < 0.05) in response to DDFM supplementation, suggesting enhanced oxidative stress resistance. These findings therefore, indicate that DDFM supplementation at 1.00% can modulate key metabolic biomarkers and improves antioxidant defense mechanisms in rabbit bucks. However, higher inclusion levels may pose potential risks related to lipid metabolism.*

**Keyword:** Date Palm, Serum Biochemistry, Lipid Metabolism, Antioxidant Enzymes, Oxidative Stress, Rabbit Bucks, Metabolic Biomarkers

1. **INTRODUCTION**

Date palm (*Phoenix* *dactylifera* L.), a member of the Arecaceae family, thrives in arid and semi-arid regions globally as stated by Awan *et al.* (2018). According to the authors, it is one of the most significant fruit crops in the Middle East and North Africa, producing edible and nutritious dates. Zare *et al.* (2019) emphasized that the date palm has long been regarded in traditional medicine, particularly for its potential to enhance fertility. Beyond its medicinal uses, they further stated that date palm also serves as an essential food source across Asia, the Middle East, and Africa, adding that in Iran, for example, regions such as Bam City in Kerman Province are well-known for cultivating date palms, underscoring their economic importance in the region.

According to Lawal (2023), date farming in Nigeria holds significant cultural significance and constitutes a way of life of the Nigerian People, adding that *Phoenix* *dactylifera* is highly valued, not only as a food source but also for its utility in traditional medicine and in the production of weaving and construction materials. Barakat and Alfheeaid (2023), stated that dates possess antioxidant, anti-inflammatory, antimicrobial, and other health-promoting effects, thanks to their rich content of phytochemicals such as phenolic compounds and flavonoids. Fernández-López *et al.* (2022) opined that consuming dates can elevate antioxidant enzyme levels, which plays a role in reducing oxidative stress associated with various diseases. In particular, phenolic acids, such as gallic and ferulic acids, have been shown to be strong free radical scavengers, protecting cellular structures from damage (Yeh *et al.* 2009). Barakat and Alfheeaid (2023) explained that dates are rich in carotenoids, phenolic compounds, flavonoids, and phytosterols, all of which contribute to their antioxidant and anti-inflammatory effects.

Rabbits are raised for various purposes, including meat, fur, wool production, laboratory research, and as companion animals (Scane, 2011). Additionally, rabbits serve as a food source for certain pets, such as snakes, and are widely used in medical research at laboratories, medical schools, and hospitals (Gillespie and Flanders, 2010; Flanders, 2012). Due to their docile nature, rabbits are commonly utilized in medical experiments, particularly for research on venereal diseases, cardiac surgery, hypertension, virology, infectious diseases, immunology, and toxin testing (Gillespie and Flanders, 2010).

This aim of this study was to investigate the effect of date palm fruit meal on serum biochemistry, lipid profile, and serum antioxidants in rabbit bucks.

1. **Materials and Methods**

**2.1 Experimental Site**

The study was conducted at the Rabbitry Unit of the Teaching and Research Farm, of Department of Animal Science*.*, University of Uyo, Akwa Ibom State. Uyo, the State capital, is located on latitude 4º 591 and 5º 041 N and longitude 7º 531 and 8º 001 E, with an elevation of about 60.96m above the sea level, according to Solomon *et al.* (2024), with a bi-modal rainfall pattern and mean annual rainfall of 2190mm and mean relative humidity of 81%.

**2.2 Sourcing and Processing of Test materials**

Dried date palm fruit were purchased from a local market in Itu Local Government Area of Akwa Ibom State, Nigeria, and used for the study. The dried date fruit were subsequently air dried and milled using an electric grinding machine, and used as dried date palm fruit meal (DDFM).

**2.3 Experimental Animals and Management**

A total of thirty-six male grower rabbits, aged 8 – 10 weeks, were used for the study. The rabbit bucks underwent a two-week acclimatization period, during which they were fed with formulated ration and *Calapogonium* *mucunoides* leaves. Prior to the commencement of the experiment, the rabbits were treated against internal and external parasites by administering ivermectin injection at 0.1ml/rabbit subcutaneously. A broad-spectrum antibiotic (Oxytetracycline L.A) was also administered intramuscularly at 0.2 ml/rabbit to check bacterial load. The rabbits were managed intensively in a wired wooden hutch, located inside an open-ended rabbit house for proper ventilation. The rabbits were provided with feed, water and forages *ad-libitum* for 168-days (24 weeks) of the experimental period. They were weighed at the beginning of the experiment and subsequently on a weekly basis.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Ingredients  | T1(0.00% DDFM) | T2(0.50% DDFM) | T3(1.00% DDFM) | T4(1.50% DDFM) |
| Maize | 45.00 | 45.00 | 45.00 | 45.00 |
| Soybean cake  | 21.00 | 21.00 | 21.00 | 21.00 |
| Wheat Offal  | 17.10 | 17.10 | 17.10 | 17.10 |
| Rice offal | 5.00 | 5:00 | 5:00 | 5:00 |
| Palm Kernel Cake | 8.00 | 8.00 | 8.00 | 8.00 |
| Bone meal | 3.00 | 3.00 | 3.00 | 3.00 |
| Common salt | 0.25 | 0.25 | 0.25 | 0.25 |
| Vit-Premix | 0.25 | 0.25 | 0.25 | 0.25 |
| Lysine  | 0.20 | 0.25 | 0.25 | 0.25 |
| Methionine  | 0.20 | 0.25 | 0.25 | 0.25 |
| TOTAL | 100.00 | 100.00 | 100.00 | 100.00 |
| Calculated Composition |  |  |  |
| Metabolizable Energy (Kcal/Kg) | 2806.30 | 2806.30 | 2806.30 | 2806.30 |
| Crude Protein (%) | 17.15 | 17.15 | 17.15 | 17.15 |
| Crude fibre (%) | 5.56 | 5.56 | 5.56 | 5.56 |
| Ether Extract (%) | 6.87 | 6.87 | 6.87 | 6.87 |

**Table 1: Composition of Experimental Diet**

**2.4 Experimental Diet**

Four experimental diets were formulated to contain dietary supplemental levels of dried date palm fruit meal (DDFM) at 0.00% (control), 0.50%, 1.00% and 1.50% and coded as T1, T2, T3 and T4 respectively. T1 contained 0.00% of the test ingredients and hence, serve as the control diet.

**2.5 Experimental Design**

The four treatment groups were assigned to the four experimental diets in a completely randomized design (CRD). Each treatment was replicated three times with nine (9) rabbits per treatment and three (3) rabbits per replicate. Each replicate received an assigned diet for twenty-four (24) weeks. The statistical model is

Yіј = μ+Tі +eіј

Where:

Yіј = single observation

μ = overall mean

Tі = Treatment effect

eіј = Random error associated with the jth observation in the ith treatment

**2.6 Data Collection**

**2.6.1 Serum Biochemistry**

Blood samples (3ml) were collected from a random doe in each replicate using a sterile needle and syringe through the external jugular vein into labeled sterile universal bottles without anticoagulant for serum biochemical analysis. The parameters evaluated included blood glucose, total protein, albumin, globulin, urea, cholesterol, alkaline phosphatase (ALP), alanine aminotransferase (AST), and aspartate aminotransferase (ALT). The levels of AST, ALT, and ALP were determined using kinetic kits as described by Ahmed and Ahmed (2010). Protein concentration was measured using the method of Pilaski (1972), while urea was calculated using Patton's method (Weiss and Wardrop, 2011), and creatinine was determined using the method by Provan *et al.* (2009). The sera were thawed, and the ALT, AST, and ALP levels were analyzed using the Audiocomb Serum Auto-analyzer (Bayer Express Plus, Bayer Germany, Serial Number 15950) in the Chemical Pathology Laboratory at the University of Uyo Teaching Hospital (UUTH), Uyo.

**2.6.2 Lipid Profile**

At the conclusion of the feeding trial, 3ml of blood was collected aseptically from the ear veins using a sterile syringe and needle into a bottle containing ethylene diamine tetra-acetic acid (EDTA) to prevent clotting. The serum was separated by centrifugation at 4000 rpm for 5 minutes at 20°C. The samples were analyzed at the University of Uyo Teaching Hospital for triglycerides, total cholesterol, high-density lipoprotein (HDL), and low-density lipoprotein (LDL) using the device. The sera were thawed, and ALT, AST, and ALP were assayed using the Auto-analyzer in the Chemical Pathology Laboratory at UUTH.

**2.6.3 Determination of antioxidants**

Following the completion of the study, 5ml blood samples were collected from one Doe per replicate into labelled plain sample bottles. The serum was separated by centrifugation at blood at 3,000 rpm for 10 min at 4ºC (Skowron *et al.,* 2018). The blood haemolysate was prepared after centrifugation as earlier stated. The sediments of erythrocytes were rinsed thrice with saline and then haemolysed with deionised water after which the activities of CAT, GPX, and glutathione reductase (GR) were determined in blood haemolysate. The activities of superoxide dismutase (SOD) was measured according to the method of Oyanagui method and adopted by Skowronm *et al.* (2018). The activity of catalase (CAT) was determined by the kinetic method of Aebi and adopted by Skowronm *et al.* (2018), finally glutathione peroxidase activity was evaluated by the kinetic method described by Paglia and Valentine and adopted by Skowronm *et al.* (2018).

**3. RESULTS**

**3.1 Serum biochemistry of rabbit bucks fed diets containing dietary levels of dried dates fruit meal.**

The results on Table 2 show the serum biochemical indices in rabbit bucks fed supplemental levels of dried date fruit meal (DDFM). Bucks fed 1.50% DDFM had significantly lower total protein levels (55.00 g/dL; p<0.05) compared to those fed 1.00% DDFM (69.00 g/dL) and the control group (68.00 g/dL). However, the 1.50% DDFM group showed similar levels to the 0.50% DDFM group (56.60 g/dL). The mean globulin was higher (p<0.05) in bucks fed T3 diet, with a mean value of 34.00 g/dL than in those fed T1, T2, and T4 respectively, which all had similar statistical values of 26.50, 23.00, and 22.50 g/dL respectively. There was a significant reduction (p<0.05) in the mean albumin in the bucks with DDFM in their diets, when compared to those of bucks without DDFM in their diet. The mean values were 41.50, 33.60, 35.00, and 32.50 g/dL for bucks in treatment groups 1, 2, 3, and 4 respectively.

Dried dates fruit meal significantly affected (p<0.05) blood urea levels with higher values been observed in T1 (5.30 mmol/L) and T2 (5.35 mmol/L) compared to T3 and T4 with lower similar values of 4.95, and 4.95 mmol/L respectively. There was a significant effect (p<0.05) of the test material on the mean aspartate aminotransferase (AST) value in the bucks. The mean AST in T2 (72.50µ/L), T3 (64.00 µ/L), and T4 (64.50 µ/L) where higher than those in T1 (61.00 µ/L), Although, this value is similar (p>0.05) to those of bucks in T3, and T4 respectively. Dried dates fruit meal failed to show any significant influence (p>0.05) on alkaline phosphatase (ALP), the mean values observed were 25.50, 27.50, 28.50, and 26.50 µ/L for rabbit bucks’ diets 1, 2, 3, and 4, respectively. Alkaline aminotransferase (ALT) were significantly reduced (p<0.05) with DDFM supplementation in the bucks’ diets compared with those without DDFM in their diets. The mean ALT was higher in T1 with value of 26.50 µ/L, while T2, T3, and T4 had similar mean values of 20.50, 20.00, and 19.00 µ/L respectively.

There was significant variation (p<0.05) in the blood creatinine levels in the rabbit bucks with DDFM supplementation. The mean value was highest (154.55 mg/dL) in the control group, without the test material, in comparison with the DDFM treated groups, which recorded individual mean values of 134.00, 112.33, and 132.00 mg/dL for groups 2, 3, and 4 respectively. Glucose on the other hand was not affected by DDFM supplementation.

**Table** **2: Serum biochemistry of rabbit bucks fed diets containing dietary levels of dried dates fruit meal.**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Parameters | T1(0.00% DDFM) | T2(0.50% DDFM) | T3(1.00% DDFM) | T4(1.50% DDFM) | SEM |
| Total protein (g/dL) | 6.80ab | 5.660bc | 69.00a | 55.00c | 2.45 |
| Globulin  | 26.50b | 23.00b | 34.00a | 22.50b | 7.21 |
| Albumin | 41.50a | 33.60b | 35.00b | 32.50b | 3.97 |
| Urea (mmol/L) | 5.30ab | 5.35a | 4.95b | 4.95b | 0.72 |
| AST (µ/L) | 61.00b | 72.50a | 64.00ab | 64.50ab | 5.20 |
| ALP (µ/L) | 25.50 | 27.50 | 28.50 | 26.50 | 1.22 |
| ALT (µ/L) | 26.50a | 20.50b | 20.00b | 19.00b | 1.04 |
| Creatinine (mg/dL) | 154.55a | 134.00b | 112.33c | 132.00b | 8.17 |
| Glucose (g/dL) | 2.95 | 2.95 | 2.75 | 2.90 | 0.05 |

AST - Alanine aspartate aminotransferase; ALP – Alanine amino phosphatase; ALT - Alanine aminotransferase; DDFM - Dried date fruit meal; SEM – Standard error of means; Means with different superscripts are significant (p<0.05)

**2.2 Lipid profile of rabbit bucks fed diets supplemented with dried dates fruit meal**

The results on the lipid profile of rabbit bucks fed diets supplemented with DDFM are presented on Table 3. The supplementation of DDFM in the bucks’ diets significantly influenced (0.05) all lipid indices evaluated except high density lipoprotein (HDL). Results on triglycerides indicated that DDFM significantly increased (p<0.05) the mean value in the rabbits fed T4 diet (1.50% DDFM) with value of (1.05), T1, T2, and T3, however, were 0.65, 0.50, and 0.65 respectively. Total cholesterol was higher in T3 (2.40), when compared with those of bucks in T1 (2.05), T2 (1.95) and T4 (2.20).

The HDL levels were 0.85, 0.90, 1.00, and 1.00 for bucks fed 0.00%, 0.50%, 1.00%, and 1.50% DDFM, respectively. No significant differences (p > 0.05) were observed among the treatment groups. The supplementation of DDFM in the busks’ diets significantly influenced (p<0.05) very-low density lipoprotein (VLDL) in the bucks. The values were higher with DDFM groups with values of 0.40, 0.50, and 0.45 for T2, T3, and T4 respectively, while the control group had mean value of 0.35. Low density lipoprotein was lower in T2 (0.65) group than those in T1 (0.85), T3 (0.90), and T4 (0.75).

**Table** **3: Lipid profile of rabbit bucks fed diets supplemented with dried dates fruit meal**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Parameters | T1(0.00% DDFM) | T2(0.50% DDFM) | T3(1.00% DDFM) | T4(1.50% DDFM) | SEM |
| Triglyceride | 0.65b | 0.50b | 0.65b | 1.05a | 0.07 |
| Total cholesterol | 2.05b | 1.95b | 2.40a | 2.20ab | 0.07 |
| HDL | 0.85 | 0.90 | 1.00 | 1.00 | 0.03 |
| VLDL | 0.35b | 0.40ab | 0.50a | 0.45ab | 0.02 |
| LDL | 0.85ab | 0.65b | 0.90a | 0.75ab | 0.06 |

a b c – Means in the same row with different superscript are significantly different (P< 0.05); DDFM – Dried dates fruit meal; SEM – Standard error of mean. HDL – High density lipoprotein, VLDL – Very low density lipoprotein, LDL - low density lipoprotein

### **2.3 Antioxidant Profile of Rabbit Bucks Fed Varying Levels of Dried Dates Fruit Meal (DDFM)**

The results on figures 1, 2, and 3, indicate that **DDFM supplementation significantly influenced superoxide dismutase (SOD), glutathione (GSH), and catalase (CAT) activities** in the rabbit bucks. Variations in these antioxidant enzymes were observed across the treatment groups. **Superoxide Dismutase (SOD) differed significantly (p<0.05) among the treatment groups**. Rabbit bucks fed **T4 (1.50% DDFM) diet recorded the highest SOD (4.60 U/mg) activity**, followed closely by those in **T3 (4.32 U/mg)**. Bucks in **T2 group (0.50% DDFM) showed intermediate values (4.12 U/mg)**, while **T1 (0.00% DDFM) had the lowest activity (3.83 U/mg)**. **Glutathione (GSH)** concentration was **significantly affected (p<0.05) by DDFM supplementation**, with higher levels observed in bucks receiving higher dietary inclusion of dried dates fruit meal. Rabbit bucks fed **T3 (1.00% DDFM) had the highest GSH (6.22 µmol/g) levels**, followed by **T4 (5.83 µmol/g) and T2 (5.46 µmol/g)**. The **lowest concentration was recorded in T1 (5.08 µmol/g)**. A significant increase (p<0.05) in **catalase activity** was observed among the treatment groups. **Bucks in T4 (3.51 U/mg) exhibited the highest catalase activity**, while **T3 (3.20 U/mg) showed moderate levels**, while bucks in **T1 (2.98 U/mg) had slightly lower catalase values**, **T2 (2.73 U/mg) recorded the least activity**.

Figure 1: Catalase activities in Rabbit Bucks fed dietary supplementation of Dried dates fruit meal.

Figure 2: Superoxide dismutase activities in Rabbit Bucks fed dietary supplementation of Dried dates fruit meal.

Figure 3: Glutathione activities in Rabbit Bucks fed dietary supplementation of Dried dates fruit meal.

1. **DISCUSSION**

**3.1 Serum biochemistry of rabbit bucks fed diets containing dietary levels of dried dates fruit meal**

The results on serum biochemistry of rabbit bucks fed diets supplemented with varying levels dried dates fruit meal (DDFM) showed significant influence on most of the parameters evaluated except on alkaline phosphatase and blood glucose level. The supplementation of DDFM reduced total protein at 0.050 and 1.50% which had mean values of 56.60 and 55.00 g/dL respectively, bucks fed 1.00% DDFM had the highest plasma protein in the study. Serum total protein is a marker of the synthetic function of the liver and a valuable guide to assess the severity of liver damage (Osigwe *et al.* (2017). Low or high total protein is an indication of liver disorders and malnutrition (Augustine *et al.* 2020). Frandson *et al.* (2009) earlier stated that functions of plasma proteins include the transport of substances such as hormones and lipids in the blood, contributing to the process of blood coagulation, and creating an effective osmotic pressure difference between the plasma and interstitial ﬂuid, adding that plasma proteins also include antibodies, which are produced by certain blood cells and are part of an overall immune response. Ahamefule *et al.* (2008), attributed high protein in serum to an indication of protein adequacy. Hence, 1.00% DDFM did not have negative effect on protein digestibility in the bucks. Attia and Al-Harthi (2015) found significant difference in broiler chickens fed diets supplemented with date wastes at 0.00 - 200g/kg diet to support this study. The result in the study agrees with the findings of Orabi and Shawky (2014) and Abdul Abdul Ameer and Hassan (2022), who reported that lower release of tissue specific enzymes and other intracellular proteins as a result of oxidative stress during metabolism could explain the drop in the serum total protein and ALT in their study. The observed low protein levels may be attributed to the high carbohydrates in dates which accounted for about 78% in the test material.

The significant variation in globulin observed in the study corroborates with the findings of Attia and Al-Harthi (2015) in broiler chickens fed dates wastes. The significantly higher globulin at 1.00% DDFM supplementation showed the ability of dates to boost the immunity of the bucks since globulin level has been used as indicator of immune responses and sources of antibody production (Unigwe *et al.* 2020). The values in the study fell within the normal range for rabbits (Merck Veterinary manual, 2012). Contrary to the findings in this report, Orabi and Shawky (2014) found no significant difference in albumin. Obikaonu *et al.* (2011) noted that serum protein, albumin and globulin depend on availability of dietary protein. Hence, the experimental diets contained sufficient dietary protein to support the physiological needs of the bucks. According to Tóthová *et al.* (2017), several physiological and pathological factors have been investigated to describe possible qualitative and quantitative alterations in the concentrations of blood proteins, reflecting the actual general health state and condition of the evaluated animals.

Just as in this study, Abdul Abdul Ameer and Hassan (2022) demonstrated that dates produce a substantial (P≤0.05) elevation in total protein, as well as ALT, AST, and ALP; however, no significant difference was found between the date-treated and control groups regarding albumin which differs from the significant variation in albumin observed in the study. While ALP was non-significantly elevated in the T3 (1.00% DDFM), and T2 (0.50% DDFM), AST was significantly elevated in T2 (0.50% DDFM), followed by bucks in T3, and T4 respectively, although values in T3 and T4 were not different from the control group. The mean ALT values took different pattern by recording significant reduction with DDFM supplementation. According to Unigwe *et al.* (2022), liver function tests (ALT, AST, ALP) provide information about the state of the liver by describing its functionality, cellular integrity and link with the biliary tract, adding that although ALT is more specific to the liver than AST, they are both considered to be two of the most significant tests for detecting liver impairment. Lower release of tissue specific enzymes and other intracellular proteins as a result of oxidative stress during metabolism could explain the drop in serum total protein and ALT (Unigwe *et al*., 2020). The method by which dates produce their hepatoprotective effects is unknown. According to Alagbe and Adegbite (2019), serum enzyme values are triggered by the presence of anti-nutrients or toxic substances in the feed of animals. Raised ALT and AST have been identified by Yin and Tong (2014) to be biomarkers of hepatocellular damage, which is induced by these enzymes leaking into the blood stream.

Serum urea and creatinine levels are an indication of kidney function (Shittu *et al.* 2023). Creatinine is a naturally occurring chemical produced by the body's metabolism. Both urea and creatinine were observed to reduce with DDFM supplementation. The results in this study showed a significant reduction in creatinine levels which was in divergence with the earlier report of Abdul Ameer and Hassan (2022) who stated the dates cause a substantial increase (P≤0.05) in creatinine, compared to the control group. The reduction in urea and creatinine suggests minimal damage to the kidney (Malo *et al.* 2024), since they are important markers for kidney function. The result in this study is in tandem with the observations of Orabi and Shawky (2014). The non-significant difference in the blood glucose levels observed in the study may not be unconnected with the lower level of glucose when compared with other sugars such as fructose, and sucrose in the fruit. Ayad *et al.* (2020) noted that fructose and glucose are the primary sugars in dates and usually comprise two-thirds of the total date flesh. The level of sucrose as stated by Shafiei *et al.* (2010) is higher in dried dates than in soft dates. Saddi *et al.* (2018) reported increase in insulin and decrease in glucose in rats which were similar to the reports of Victor *et al.* (2017) and El-Abed *et al.* (2017). This, according to Mirghani (2024) is possible due to the positive effects of flavonoids on the islet β cells and decreased gastric emptying due to the phenols. Most biochemical indices evaluated were within normal reference ranges for healthy rabbits (Merck Veterinary Manual, 2012), demonstrating the ability of dates to maintain and improve normal functions of the heart, liver, kidney and the overall immunity of the bucks.

**3.2 Lipid profile of rabbit bucks fed diets supplemented with dried dates fruit meal**

The results on lipid profile in rabbit bucks fed diets supplemented with varying levels of DDFM showed significant effect on all parameters evaluated except in high density lipoprotein (HDL). The study observed a very significant increase in triglyceride at 1.50% DDFM supplementation in the bucks diets. Awan *et al.* (2019) reported a significant reduction in triglycerides in rats fed 20% dates fruit. Alqarni *et al.* (2019) reported reduced total cholesterol, low-density lipoproteins (LDLs), and triglycerides among hypercholesterolemic rats. The differences in the studies may be due to specie differences in the animals used, forms and quantities of administration. Frandson *et al.* (2009) documented that triglycerides consist of a glycerol molecule with three fatty acids attached and are also known as neutral fats, while adding that triglycerides are the primary form of lipid storage in adipose tissue in animals. Because triglycerides are not soluble in water, most are not transported as individual molecules in blood plasma. For transport, they are combined with other lipids and proteins into relatively large particles known as lipoproteins. In this form they can be transported from site to site within the body (Frandson *et al.* 2009). Ettu *et al.* (2019) did not find significant difference in triglycerides in their study.

Supplementing the bucks’ diet with 1.00% DDFM resulted in elevated levels of total cholesterol, high-density lipoproteins (HDL), very-low density lipoproteins (VLDL) and low-density lipoproteins respectively. This was followed closely by 1.50% DDFM supplementation in the bucks’ diet. Cholesterol, a hydrophilic lipid, as described by Awan *et al.* (2019), is a precursor of several hormones, bile acids and vitamin D and is required by the body from exogenous sources and is endogenously synthesized through mevalonate pathway. The amount is regulated through feedback control mechanisms (Rafieian-Kopaei *et al.* 2014). Awan *et al.* (2019), observed significant difference in serum triglycerides, LDL and HDL. Cholesterol itself is an essential constituent of the cell membrane of all animal cells (Frandson *et al.* 2009), however, the 2.40 mmol/L observed at 1.00% DDFM supplementation in this study is slightly above the 0.30 – 2.10 mmol/L recommended by Merck Veterinary manual (2024), implying potential risk of cardiac diseases. Tehrani *et al.* (2013) described high density lipoprotein (HDL) as good cholesterol and is found to exert prophylactic potential against coronary heart disease possibly through reverse cholesterol transport mechanism and by reducing the LDL associated oxidative stress. Though HDL was not significant in this study, the value observed at 1.00% supplementation portrays dates potential in preventing heart diseases, however, this may not be absolute since the high total cholesterol value observed at this level of supplementation is undesirable in the body.

### **3.3 Antioxidant Enzyme Activities in Rabbit Bucks Fed Varying Levels of Dried Dates Fruit Meal (DDFM)**

Oxidative stress is a known contributor to various health disorders, and antioxidant enzymes such as **superoxide dismutase (SOD), glutathione (GSH), and catalase (CAT)** play crucial roles in mitigating its effects by neutralizing reactive oxygen species (ROS). The SOD values observed in the study increased significantly with **1.00% (4.32 U/mg) and 1.50% (4.60 U/mg) DDFM supplementation respectively**, while lower value was recorded in the control group (**3.83 U/mg**). These values fall within the normal physiological range for rabbits and indicate that **higher levels of DDFM enhanced the ability of the bucks to convert harmful superoxide radicals into less toxic hydrogen peroxide**. This finding aligns with the report of Nandi *et al.* (2019), which emphasized that **SOD plays a primary role in cellular defense against oxidative damage**. Similarly, Lubo *et al.* (2022) noted that **SOD activity is critical in preventing mitochondrial dysfunction, a major factor in degenerative diseases**. The results also suggest that **DDFM may contain bioactive compounds that stimulate endogenous antioxidant responses**. Zelko in Zheng *et al.* (2023) described SOD as a kind of enzyme containing Cu, Mn, Zn, and other metal ions that is widely distributed in plants, animals, and microorganisms. Zheng *et al.* (2023) noted that in the process of eliminating free radicals, SOD requires cofactors such as iron, manganese, or copper and zinc to exert maximum catalytic activity when metabolizing toxic intermediates. The presence of the above-named minerals (iron, manganese, zinc, etc) in DDFM may have contributed to the higher values in the DDFM supplementation group, suggesting that DDFM supplementation played a role in oxidative stress management.

The observed **glutathione (GSH) values ranged from 5.08 µmol/g in T1 to 6.22 µmol/g in T4**, showing a significant increase with DDFM supplementation. **GSH is a key intracellular antioxidant that helps detoxify hydrogen peroxide and lipid peroxides through its role as a cofactor for glutathione peroxidase (GPx1)**. According to Lubo *et al.* (2022), **glutathione levels are closely linked to cellular redox balance, and its depletion is a marker of oxidative stress-related disorders**. This suggests that DDFM may support improved antioxidant defense by enhancing glutathione production, which is crucial for cellular detoxification.

Catalase activity also varied significantly across the treatment groups, with **T4 (3.51 U/mg) recording the highest activity**, followed by **T3 (3.20 U/mg) and T2 (2.98 U/mg)**. The lowest activity was observed in **T1 (2.73 U/mg)**. **Catalase plays a key role in breaking down hydrogen peroxide into water and oxygen, preventing oxidative damage to cellular components**. This statement is consistent with reports from Nandi *et al.* (2019), which documented **the importance of catalase in preventing hydrogen peroxide accumulation, which can otherwise lead to oxidative stress and cellular apoptosis**. Additionally, Lubo *et al.* (2022) highlighted that **catalase deficiency is associated with increased risks of metabolic and neurodegenerative disorders**. The observed increase in catalase activity with DDFM supplementation suggests that **DDFM may upregulate antioxidant enzyme expression, thereby improving oxidative resilience in bucks**. Catalase as stated by Nandi *et al.* (2019), is one of the most important antioxidant enzymes present in almost all aerobic organisms. Catalase breaks down two hydrogen peroxide molecules into one molecule of oxygen and two molecules of water in a two-step reaction (Nandi *et al.*, 2019). This pattern suggests that DDFM supplementation may enhance catalase activity, which is vital for breaking down hydrogen peroxide and protecting cells from oxidative damage.

The findings from this study demonstrate that **DDFM supplementation significantly enhanced the activities of key antioxidant enzymes (SOD, GSH, and CAT), indicating an improved oxidative defense system in bucks receiving higher supplementation levels**. These values fall within established physiological ranges, suggesting that **DDFM supplementation is not only safe but may also provide functional benefits by strengthening the body’s antioxidant mechanisms**.

1. **CONCLUSION**

In conclusion, 1.00% dietary supplementation with dried date palm fruit meal may positively influence serum biochemical parameters, lipid metabolism, and antioxidant defense mechanisms in rabbit bucks.

**Disclaimer (Artificial intelligence)**

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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