International Journal of Animal Science, Husbandry and Livestock Production (IJASHLP) ISSN: 2141-5191, Vol. 9(2), pp. 469-477, May, 2023. Available online at www.advancedscholarsjournals.org © Advanced Scholars Journals

Full length Research paper

Blood Serum Contents and Fatty Acid Profiles of Meat from Different Chicken Strains in Ethiopia

***Getachew Bekele Fereja[1], Wondmneh Esatu[3],Gebeyehu Goshu[1], Aberra Melesse[2], and Tadelle Dessie[3]**

[1]Addis Ababa University, College of Veterinary Medicine and Agriculture, Department of Animal Production, P O Box 34, Bishoftu, Ethiopia.
[2]Hawassa University, School of Animal and Range Sciences, P O Box 5, Hawassa, Ethiopia.
[3]International Livestock Research Institute (**ILRI**),African Chicken Genetic Gains **(ACGG)**, Addis Ababa, Ethiopia.

Accepted 28th April, 2023

This study aimed to investigate the blood serum contents, fatty acid profiles of meatand their correlations. Atotal of 96 mixed sex matured indigenous chicken strains from Abobo (Ab), Gambella Ketema Zuria (GKz), Lare (La), and Itang (It), were used to determine blood serum contents, of which 32 chickens were also used for fatty acid profile investigation. Completely Randomized (CRD) design was used to analyze the data. Blood serum contents and fatty acid profiles of chickens' meat were determined by Roche/Hitachi cobas c 501 and GC standard procedures, respectively. High-density lipoprotein (HDL), Low-density lipoprotein (LDL), Triglyceride, (TG) and Total cholesterol (TC) were significantly different (P≤0.05) between both sexes. The level of HDL was inversely correlated with LDL, TG, and TC. The male chicken's strains had significantly lower (P≤0.05) HDL, but higher LDL TG, and TC than female. All investigated saturated fatty acids (SFAs) (Palmitic, Myristic, Decanoic, Pentadecanoic, Margaric, Stearic, and Tetradecylic) were non-significantly different (P≥ 0.05) between different chicken strains studied. However, there were significant differences (P≤0.05) between both sexes. All investigated polyunsaturated fatty acids (PUFAs) (arachidonic acid, linoleic acid, alpha-linolenic acid, and phthalic acid) were non-significantly different (P≥ 0.05) between the different chicken strains studied. However, there were significant differences (P≤ 0.05) between both sexes of different chicken strains studied. UFA was significantly lower (P≤0.05) in male chicken than female. The mean values of the PUFA/MUFA were non-significantly different (P≥0.05) among different chicken strains and both sexes. Chicken strains have higher contents of blood serum (TC, TG, LDL) and SFA in meat might cause human health problems. Therefore, further investigation and studies are needed in the future.

Keywords: blood serum, chicken strains, correlation, and fatty acid profiles

INTRODUCTION

The chicken production sector has not only met protein supply but also reduced poverty rapidly through employment and income generation worldwide. A Blood Serum profile of chickens gives crucial information for the evaluation of health status which shows many metabolic changes of organs and tissues. The blood serum profiles of indigenous and broiler chickens vary from each other in different regions of the world. It is very crucial to investigate blood serum profile of indigenous and broiler chickens for description of the health status[1].The blood serum parameters provide important information on the health status of an animals[2]. This information is not only useful for management practices but also equally helpful in breeding programs for the genetic improvement of local poultries. It is important to know the normal physiological values under local conditions for proper management, feeding, breeding, prevention, treatment, and control of livestock diseases.

The dietary cholesterol concentration and fatty acid profiles of lipid fractions are incorporated from

*Corresponding author: e-mail: gechobek@gmail.com,

atherosclerosis and coronary artery diseases in humans' lifespan. The Saturated fatty acids (SFA) enhance the plasma cholesterol and low-density lipoprotein-cholesterol (LDL-c) levels, whereas the polyunsaturated fatty acids (PUFA) reduce the plasma cholesterol and LDL-c concentrations in humans. A chicken meat is healthier than other meat sources for human consumption because of its low cholesterol and fat level, but many studies have been conducted to decrease the SFA and cholesterol level of chicken meat.

Fat and fatty acids in muscle and adipose tissues are among the major factors that influence meat quality, particularly nutritional value, and palatability. The changes in the dietary fatty acid (FA) composition could be reflected in the blood that in turn would be transported to target organs such as muscle. The poultry meat is considered healthier owing to its relatively lower fat content compared with other animal meat[3]. Overall, the lipids of the muscle fibers contain a proportion of phospholipids, triacylglycerol, and cholesterol. Fatty acids of triacylglycerol are made up mainly of saturated fatty acids (SFA) and monounsaturated fatty acids (MUFA).Red muscles contain a higher proportion of phospholipids than white muscles and thus a relatively higher amount of PUFA[4].

Higher PUFA level in muscle membranes leads to increased susceptibility of meat and meat products to lipid oxidation. PUFA cause rapid oxidative changes, which impair organoleptic characteristics, shorten meat shelf-life, and produce off-flavours[5]. Manipulation of PUFA composition without affecting product quality has been a challenge for poultry scholars. A current interest in increasing the n-3 PUFA content of meat and eggs enhances the need for additional antioxidant protection. Approaches that are effective, safe and of low-cost for controlling storage stability of the poultry meat are extremely important to the industry.A logical basis for the intention of this research was that analysis of the blood Serum contents and fatty acid profiles of meat from Abobo (Ab), Gambella Ketema Zuria (GKz), Lare (La), and Itang (It) chickens to produce healthy eggs and meats for consumption were not studied in the study area. Therefore, the objective this study was to investigate the blood serum contents, fatty acid profiles of meat, and their correlations.

MATERIALS AND METHODS

Description of the Study Area

The study was conducted at Gambella Agricultural Research Institute (GARI), which is 695 km far from Addis Ababa, and is in Anuak zone of Gambella regional state, at the confluence of the Baro River and its tributary the Jajjebe, the GARI has a latitude and longitude of 8º15'N34º35'E and an elevation of 526 meters. It is surrounded by Gambella Ketema Zuria district. The annual temperature varies from 27ºC to 35ºC. The maximum temperature occurs in mid-March and is about 45ºC. The annual rainfall varies from 900-1500mm.

Experimental chickens and Sample preparation

A total of 96 chickens (48 males and 48 females) at the age of 24 weeks from four different strains were transported from Gambella Agricultural Research Institute to Gambella University for the slaughtering purposes. The chickens were slaughtered after stunning and following the guidelines approved by the Addis Ababa University, College of Veterinary Medicine and Agriculture animal care and use committee (**ref.no, VM/ERC/O1/12/020**).The chickens were scalded at recommended water temperature (53ºC) and defeated. The carcasses were eviscerated, washed, and placed in airtight plastic bags and carcasses were chilled for 24 hours at 4˚C. The prepared carcass samples were transported for laboratory analysis.

Blood Serum Contents and Meat fatty acid profiles Investigation of Blood Serum Contents

The Blood samples were collected from four different chicken strains and sexes during the study. A total of 12 blood samples were collected from each chicken strain. The total blood samples collected from all chicken strains were 96 (4*12*2). Then,10 ml of blood was taken from axillary vein by using disposable syringe. The blood samples were centrifuged at 3,000 g for 10 min, and the serum was stored in a freezer at -20°C until for laboratory analyses.

The blood sample collection and serum separation were done at Gambella University, animal science laboratory, Gambella. Total cholesterol, Triglycerides, High density lipoproteins and Low-density lipoproteins were determined automatically from serum samples by Roche/Hitachi cobas c 501 systems using the enzymatic colorimetric method (Roche 501) at Ethiopian Public Research Institute (EPHI). The results were expressed in mg/dl for each serum samples.

Investigation of Meat Fatty Acid Profile

The meat was dried at the temperature of 60˚C for 72 hours using an oven according to the standard meat drying method. After drying, the meat size was reduced by grinder. Fatty acid methyl ester (FAME) was prepared. Ten gram of homogenate meat was weighed into a screw cap glass vial along with an internal standard solution of tridecanoic acid (0.5 mg/ ml in methanol). The Vials were placed in a water bath for incubation at 55ºC.Hexane was used to extract FAME prior to analysis by gas liquid chromatography (GC). Separation of FAME was carried. The separation of FAME was equipped with a flame ionization detector (FID). The Gas Chromatography (GC) was operated.

The injector was held at 250°C fitted with deactivated split/splitless liner packed with glass wool. The column head pressure was 195.6kPa and a total flow rate of 129.1mL/min.

The oven method was carried on by increasing temperature at 35°C held for 2 min, increased to a temperature of 170°C at the rate of 4°C/min, held for 4 min, then increased to a temperature of 240°C at the rate of 3.5°C/min, held for 7 min. The Hydrogen was used as the carrier gas and the FID was operated at 250°C. Fatty acids was identified based on the similarity of retention times with the GC reference standards. Finally, 32(8 from each chicken strains) meat samples were analyzed for fatty acid profile at Addis Ababa University, faculty of Natural Science, Department of Chemistry.

Research Design

The data was analyzed using completely Randomized (CRD) design. A total of 96 (4*12*2) blood samples were collected and separated to obtain the serum samples from each sex of the chicken strains used. The separated serums were taken to Ethiopian Public Health Institute to determine total cholesterol (TC), triglyceride (TG), low density lipoprotein (LDL) and high-density lipoprotein (HDL).

Statistical Analysis

All data were coded and recorded in Microsoft excel sheet. Descriptive statistics such as mean, frequency and percentage were calculated, and all the data were analyzed. The descriptive statistics (mean±SE) for numerical data was subjected to one way analysis of variance (ANOVA) using the General Linear Model (GLM) procedure of the Statistical Analysis System (SAS)[6] version 9.1. The means were compared using Tukey`sstudentized range test method at p<0.05. The statistical model used was:

$Y_{ijk}=\mu + S_{1i} + C_{2j} + (S_1C_2)_{ij} + e_{ijk}$

Were:

Y_{ijk} = the response variables

μ = the overall Mean

S_{1i} = the effect of sex

C_{2j} = the effect of chicken strains

$(S_1C_2)_{ij}$ = The effect of interaction between sex and chicken strains

e_{ijk} = Random error

RESULTS AND DISCUSSION

The Serum profiles/components of different chicken strains

The serum profiles such as HDL, LDL, TG, and TC of the different chicken strains of Ab, GKz, La, and It were investigated during the study period (Table 1). Results showed that, the mean values of HDL, for Ab, GKz, La, and It were 85.94±1.07, 87.10±0.06, 86.03±0.42, and85.92±0.53 mg/dl, respectively. GKz had significantly higher HDL concentrations (P≤0.05) than Ab, La, and It chicken strains. HDL concentrations were significantly higher (P<0.05) in female (94.28±0.09) than male chicken strains (78.24 ± 0.02). The HDL concentrations in female and male chicken strains of Ab and GKz were 93.82 ± 0.53, 78.05 ±0.54, 95.26 ± 0.04, and 78.94 ± 0.02 mg/dl, respectively (Table 2). Similarly, HDL concentrations were significantly different (P<0.05) in female and male chicken strains of Ab, and GKz.

The HDL concentration of female and male chicken strains of It and La were 93.78±0.25, 77.99±0.28, 94.05±0.20, and 78.01±0.21 mg/dl, respectively (Table 2). Likewise, female chicken strains of It, and La had significantly higher HDL concentrations (P<0.05) than the male. The mean values of the HDL concentration (86.26 ± 0.06) found in this study was lower than, the values reported for indigenous (103.33 ± 12.61) and broiler (131.31± 5.84) chickens by Masudet al.[7] and the value reported by Wang and Musa[8]forRugao (118.15±3.99) and Anka (93.97±2.78) chickens.HDL concentrations (sex wise) found in the present study were similar to a previous study conducted by Fatimah *et al.,*[9]. There were significant (P<0.05) differences in serum HDL levels among four chicken strains (Ab, GKz, La, and It).

Lipoprotein lipase and apolipo proteins (apoA-I; apoE; apoC-II) can regulate the HDL contents[10]. Hepatic lipase may impress the bustle of HDL concentration[11]. HDL concentration might be affected by esterase and oxidase[12]. The mean values of LDL of the Ab, GKz, It, and La chicken strains were 78.66± 0.04, 78.27±0.07, 79.52±0.03, and 79.46±0.06, mg/dl, consequently. It chicken strain had significantly higher (P<0.05) LDL concentration than the Ab, GKz, and La chicken strains.LDL concentration was significantly (P<0.05) higher in male (85.59±0.02) than female (72.61±0.03) chicken strains. The current findings revealed that, the LDL concentrations of the female and male chicken strains of Ab and GKz were 72.64 ± 0.01, 85.67 ± 0.03, 71.82 ± 0.03, and 84.72 ± 0.04 mg/dl, sequentially.

LDL concentration was significantly (P≤0.05) higher in male than female Ab, and GKz chickens. The present study revealed that, the LDL concentration of female and male chicken strains of the It and La were 73.03 ± 0.02, 86.01 ± 0.01, 72.96 ± 0.02, and 85.99 ± 0.04, mg/dl, (Table 2) respectively. LDL concentrations were significantly higher (P≤0.05) in male than female of It, and La chicken strains. The current results showed slightly higher LDL concentration in both sexes than those reported by Masud*et al.,*[7]who found that the indigenous chicken (25.80±9.06 mg/dl) had significantly (P<0.001) lower serum LDL content than broiler (81.94±4.19 mg/dl) chickens and Hassan *et al.,*[13]who stated that the level of LDL in Male significantly (P<0.05) higher than female in Anka (52.66±5.63,

Table 1. Serum profiles/components different chicken strains (mean ± SE)

Chicken strains	Serum profiles			
	HDL	LDL	TG	TC
Ab	85.94 ± 1.07^{b}	78.66 ± 0.04^{b}	123.77 ± 0.23^{ab}	148.46 ± 0.07^{ab}
GKz	87.10 ± 0.06^{a}	78.27 ± 0.07^{b}	122.96 ± 0.19^{b}	147.66 ± 0.04^{b}
La	86.03 ± 0.42^{ab}	79.46 ± 0.06^{b}	124.58 ± 0.25^{b}	149.15 ± 0.11^{a}
It	85.92 ± 0.53^{b}	79.52 ± 0.03^{a}	124.61 ± 0.31^{a}	149.39 ± 0.13^{a}
p- value	*	*	*	*
sex				
Female	94.28 ± 0.09^{a}	72.61 ± 0.03^{b}	121.13 ± 0.05^{b}	140.24 ± 0.03^{b}
Male	78.24 ± 0.02^{b}	85.59 ± 0.02^{a}	126.71 ± 0.01^{a}	157.09 ± 0.06^{a}
p-value	***	***	***	***
Overall mean	86.26 ± 0.06	79.10 ± 0.03	123.92 ± 0.03	148.67 ± 0.05
CV	5.13	8.92	10.42	4.87

*^{abc}Mean values under the same category across column that bear different superscript letters are significantly different, Ns = P > 0.05, ** = P≤ 0.01, * = P≤ 0.05, SE = standard error of mean, Ab=Abobo, GKz= GambellaKetemaZuria, It= Itang, and La= Lare chicken strains. HDL= high density of lipoprotein, LDL= Low density of lipoprotein, TG= Triglyceride, and TC= total cholesterol.*

Table 2. Relationship of serum profiles/components between sex and chicken strain (mean ± SE)

Chicken strain	**Sex**	**Serum profiles**			
		HDL	**LDL**	**TG**	**TC**
Ab	F	93.82 ± 0.53^{a}	72.64 ± 0.01^{b}	121.15 ± 0.11^{b}	139.99 ± 0.04^{b}
	M	78.05 ±0.54^{b}	85.67 ± 0.03^{a}	126.38 ± 0.12^{a}	156.93 ± 0.03^{a}
p-value		***	***	*	***
Overall mean		85.94 ± 0.05	79. 16 ± 0.10	123.77 ± 0.18	148.46 ± 0.03
CV		**6.34**	**17.61**	**12.59**	**6.87**
GKz	F	95.26 ± 0.04^{a}	71.82 ± 0.03^{b}	120.05 ± 0.09^{b}	139.26 ± 0.03^{b}
	M	78.94 ± 0.02^{b}	84.72 ± 0.04^{a}	125.87 ± 0.08^{a}	156.06 ± 0.01^{a}
p-value		***	**	*	**
Overall mean		87.10 ± 0.03	78.27 ± 0.04	122. 96 ± 0.08	147.66 ± 0.02
CV		**7.66**	**20.63**	**11.55**	**4.77**
It	F	93.78 ± 0.25^{a}	73.03 ± 0.02^{b}	121.87 ± 0.15^{b}	141.08 ± 0.07^{b}
	M	77.99 ± 0.28^{b}	86.01 ± 0.01^{a}	126.89 ± 0.16^{a}	157.71 ± 0.06^{a}
p-value		***	**	*	**
Overall mean		85.89 ± 0.53	79.52 ± 0.03	124.38 ± 0.31	149.39 ± 0.13
CV		4.69	15.77	9.91	6.94
La	F	94.05 ± 0.20^{a}	72.96 ± 0.02^{b}	121.45 ± 0.13^{b}	140.64 ± 0.06^{b}
	M	78.01 ± 0.21^{b}	85.99 ± 0.04^{a}	127.71 ± 0.12^{a}	157.66 ± 0.05^{a}
p-value		***	**	*	**
Overall mean		86.03 ± 0.21	79.48 ± 0.03	124.58 ± 0.13	149.15 ± 0.06
CV		4.33	16.86	7.43	5.96

*^{ab}Mean values under the same category across column that bear different superscript letters are significantly different, Ns = P > 0.05, ** = P≤ 0.01, * = P≤ 0.05, SE = standard error of mean, Ab=Abobo, GKz= GambellaKetemaZuria, It= Itang, and La= Lare chicken strains. HDL= high density of lipoprotein, LDL= Low density of lipoprotein, TG= Triglyceride, and TC= total cholesterol.*

34.22± 5.21) and Rugao (46.58±7.05, 24.54±5.57) chickens, respectively. Lipoprotein lipase and apoB-100 and apoE can regulate the LDL contents[10]. Hepatic lipase may influence the activity of serum LDL levels[7,11]. The suppression of hepatic lipogenic enzymes is attributed to their ability to suppress or inhibit the expression of genes coding for lipogenic proteins[14]. Aspartate transaminase (**AST**) and Alanine transaminase (**ALT**) may determine the liver function and LDL concentration[7].

The mean values for the TG concentrations of Ab, GKz, La, and It, chicken strains were 123.77 ± 0.23, 122.96 ± 0.19, 124.58 ± 0.25, and 124.61 ± 0.31, mg/dl, respectively. The It chicken strain had significantly higher TG concentrations (P<0.05) than, Ab, GKz, and La chicken strains. TG concentrations were significantly higher (P≤0.05) in male (126.71±0.01) than female (121.13±0.05) among different chicken strains studied. TG concentrations of female and male of the Ab, and GKz chicken strains were 121.15 ± 0.11, 126.38 ± 0.12, 120.05 ± 0.09, and 125.87 ± 0.08 mg/dl, respectively as shown in Table 2. The TG concentrations were significantly higher (P≤0.05) in male than female Ab, and GKz chicken strains. The TG concentration of female and male of the It, and La chicken strains were 121.87 ± 0.15, 126.89 ± 0.16, 121.45 ± 0.13, and 127.71 ± 0.12, mg/dl, respectively. Male had significantly higher TG concentrations (P≤0.05) than female It, and La chicken strains. In the current study the TG concentrations were lower than that of the

values reported by Hassan *et al.,*[13], the serum TG levels were significantly (P<0.05) lower in Dandarawi (139.15 mg/dl) than that of the Dokki (143.16 mg/dl) of native Egyptian chickens. Sanchai*et al.,*[15] stated its reason and said that slow growing chickens had significantly (P<0.05) lower TG compared to fast growing chickens. The TG concentration might be varied due to acetyl-CoA carboxylase[16] and fatty acid synthase[8].TG concentration might be influenced by insulin activities[12],acyl-Coenzyme oxidase1 (**ACOX1**) and carnitine palmitoyltransferase1 (**CPT1**)[14], stearoyl-coadesaturase (SCD)[11]and *Triglyceride lipase* (**TAG-Lipase**)[14]. *Adipogenesis*inhibitors [1, 25 - $(OH)_{2D3}$] could also affect mRNA abundance and expression of genes to influence fat and TG[17]. The mean value of the TC, for Ab, GKz, La, and It, chicken strains were 148.46±0.07, 147.66±0.04, 149.15±0.11, and 149.39±0.13, mg/dl, respectively.

Likewise, It, chicken strain had significantly higher TC concentrations ($P \leq 0.05$) than Ab, GKz and La chicken strains. TC concentrations were significantly higher ($P \leq 0.001$) in male (157.09 ± 0.06) than female (140.24 ± 0.03) among chicken strains. The TC concentrations of female and male of Ab, and GKz chicken strains were 139.99 ± 0.04, 156.93 ± 0.03, 139.26 ± 0.03, and 156.06 ± 0.01, mg/dl, respectively.TC concentrations were significantly higher ($P \leq 0.001$) in male than female of Ab, and GKz chicken strains. The TC concentrations of female and male of the It, and La, chicken strains were 141.08 ± 0.07, 157.71 ± 0.06, 140.64 ± 0.06, and 157.66 ± 0.05, mg/dl, respectively. Similarly, male had significantly higher TC concentration ($P \leq 0.01$) than female of It, and Lachicken strains. Results of the present study were concurrent with Kalita*et al.,*[18]who reported that slow growing chickens had significantly (P<0.05) lower serum TC concentration (152.25±5.39 mg/dl) than fast growing (180.91±6.49 mg/dl) chickens and similarly Wang and Musa[8] reported that male had significantly (P<0.01) higher level of TC than female in Anka and Rugao chickens.

Lipogenic enzymes such as lipoprotein lipase, hepatic lipase, HMGCoA-reductase, and cholesterol 7a-hydroxylase might affect endogenous TC concentration[9,11]. Lipoproteins were found highly sensitive to hormonal and genetic modulation[10]. The difference in cholesterol and other steroid levels could affect the production and reproduction performances[18]. Generally, it can be recommended that indigenous (local) chicken strains are more suitable to the consumers due to the comparatively low level of serum profiles at the usual finisher period.

The fatty acid profile of different chicken strains studied

Table 3 shows the fatty acid profiles of meat from Ab, GKz, It, and La chicken strains. The mean values of Palmitic (SFA) female and male meat of It chicken strain (20.73±0.08, 21.59 ±0.02) was significant higher (P< 0.05) than the Ab (19.26 ± 0.03, 20.17±0.05), GKz (19.23 ±0.11, 19.89 ±0.16,) and La (20.45 ±0.03, 20.93 ±0.14) meat of female and male chicken strains respectively. Myristic acid contents were significantly lower (*P > 0.05*) in meat of female and male GKzchicken strain (0.46 ±0.07, 0.51 ±0.08) than the Ab (0.47 ±0.01, 0.53 ±0.04), It (0.50 ±0.01, 0.57 ±0.12) and La (0.49 ±0.10, 0.55 ±0.09) meat of female and male chicken strains respectively. The mean value of stearic acid contents in It (9.73 ±1.13,9.85 ±0.79) female and male chicken strain meat was significantly higher (P<0.05) than the Ab (9.39±1.15, 9.53±0.92), GKz (9.38±0.87, 9.46±1.24) and La (9.63±1.15, 9.64±1.13) meat of female and male chicken strains respectively.

From the contents of SFAs, non-significant differences (P< 0.05) were observed in all investigated acids (Palmitic, Myristic, Decanoic, Pentadecanoic, Margaric, Stearic, and Tetradecylic). However, significant differences (P< 0.05) were observed between different chicken strains (male and female).Saturated fatty acid (SFA) was significantly higher (P<0.05) in male (33.63±0.54) than female (31.28±0.77) chickens as Adipogenesis inhibitors (1, 25 - (OH) 2D3) are sex specific and might affect mRNA, acetyl-CoA carboxylase[8] and SCD activity[11,17]. Benabdelmoumene *et al.*,[19] also noted that saturated fatty acid (SFA) was significantly higher (P<0.05) in male (33.24±2.19) than female (28.69±1.32) Naked-Neck chickens.

The mean values of Linoleic acid (PUFA) inmeat from female and male GKzchicken strain (22.04 ±1.12, 21.62 ±0.07) was significant higher (P< 0.05) than the Ab (21.93 ±1.03, 21.69 ±1.01), It (21.29±0.06, 20.86 ±1.04) and La (21.31 ±0.97, 21.17 ±1.15) meat from female and male chicken strains respectively. From the contents of PUFAs the alpha-linolenic acid contents of different chicken strains was lower in female and male chicken meat of Ab, (0.79 ±0.02, 0.77 ±0.01) GKz, (0.83 ±0.04, 0.81 ±0.07) It, (0.78 ±0.01, 0.75 ±0.06) and La(0.78 ±0.03, 0.76 ±0.04) respectively.

From the contents of PUFAs, non-significant differences (P< 0.05) were observed in all investigated acids (arachidonic acid, linoleic acid, alpha-linolenic acid, and phthalic acid). However, significant differences (P< 0.05) were observed between different chicken strains (male and female).

The mean values of all MUFAs, acids (Oleic, Myristoleic, Benzoic, Eicosenoic, and Palmitoleic) for the different chicken strains studied were significantly influenced both sexes of chickens due to stearoyl-CoA desaturase (**SCD**) and lipase activities. The mean value of Oleic acid (MUFA) in the meat from all female chicken strains (Ab, GKz, It, and La) (39.20 ±1.14, 39.26 ±1.17, 38.48±0.24, and 38.81 ±0.85) were significant higher (P< 0.05) than the meat from male chickens (38.74 ±1.21, 39.14 ±0.16, 38.11 ±1.11, and 38.52 ±1.22) respectively. MUFAs (Myristoleic acid and Benzoic) had the lowest concentration ($P \leq 0.05$) than the Oleic acid, Eicosenoic, and Palmitoleic acids from all chicken strains studied. The present results were

Table 3. Fatty Acid profile of different chicken strains' meat studied (mean ± SE)

FA profiles (mg/g)	Chicken strains								P - value		
	Ab		GKz		It		La		CS	S	CS*S
	F	M	F	M	F	M	F	M			
Palmitic	19.26 ± 0.03^{b}	20.17±0.05^{a}	19.23 ±0.11^{b}	19.89 ±0.16^{a}	20.73±0.08^{b}	21.59 ±0.02^{a}	20.45 ±0.03^{b}	20.93 ±0.14^{a}	Ns	*	Ns
Myristic	0.47 ±0.01^{b}	0.53 ±0.04^{a}	0.46 ±0.07^{b}	0.51 ±0.08^{a}	0.50 ±0.01^{b}	0.57 ±0.12^{a}	0.49 ±0.10^{b}	0.55 ±0.09^{a}	Ns	*	Ns
Decanoic	0.25 ±0.05^{b}	0.37 ±0.01^{a}	0.23 ±0.03^{b}	0.33 ±0.07^{a}	0.29 ±0.02^{b}	0.43 ±0.04^{a}	0.28 ±0.06^{b}	0.41 ±0.02^{a}	Ns	*	Ns
Pentadecanoic	0.52 ±0.12^{b}	0.57±0.14^{a}	0.49±0.08b	0.53 ±0.05^{a}	0.56 ±0.14^{b}	0.61 ±0.11^{a}	0.54 ±0.09^{b}	0.58 ±0.17^{a}	Ns	*	Ns
Margaric	0.23 ±0.02^{b}	0.27±0.06^{a}	0.22 ±0.14^{b}	0.26 ±0.11^{a}	0.26 ±0.09^{b}	0.29 ±0.03^{a}	0.25 ±0.04^{b}	0.28 ±0.08^{a}	Ns	*	Ns
Stearic	9.39 ±1.15^{b}	9.53±0.92^{a}	9.38 ±0.87^{b}	9.46 ±1.24a	9.73 ±1.13^{b}	9.85 ±0.79^{a}	9.63 ±1.15^{b}	9.64 ±1.13^{a}	Ns	*	Ns
Tetradecylic	0.14 ±0.07^{b}	0.17±0.01^{a}	0.13 ±0.04^{b}	0.16 ±0.05^{a}	0.16 ±0.02^{b}	0.17 ±0.05^{a}	0.15 ±0.08^{b}	0.18 ±0.01^{a}	Ns	*	Ns
SFA	**30.26 ±0.21**	**31.61 ±0.18**	**30.14 ±0.19**	**31.14 ±0.25**	**32.23 ±0.21**	**33.51 ±0.17**	**31.79 ±0.22**	**32.57 ±0.23**			
Arachidonic	2.68 ±0.09^{a}	2.53±0.81^{b}	2.49 ±0.07^{a}	2.41 ±0.93^{b}	2.46 ±0.65^{a}	2.39 ±0.48^{b}	2.48 ±0.72^{a}	2.43 ±0.89^{b}	Ns	*	Ns
Linoleic acid	21.93 ±1.03^{a}	21.67 ±1.01^{b}	22.04 ±1.12^{a}	21.68 ±0.07^{b}	21.29±0.06^{a}	20.86 ±1.04^{b}	21.31 ±0.97^{a}	21.17 ±1.15^{b}	Ns	*	Ns
Alpha linolenic	0.79 ±0.02^{a}	0.77 ±0.01^{b}	0.83 ±0.04^{a}	0.81 ±0.07^{b}	0.78 ±0.01^{a}	0.75 ±0.06^{b}	0.78 ±0.03^{a}	0.76 ±0.04^{b}	Ns	*	Ns
Phthalic acid	1.49 ±0.05^{a}	1.28 ±0.04^{b}	1.52 ±0.08^{a}	1.32 ±0.03^{b}	1.44 ±0.02^{a}	1.22 ±0.07^{b}	1.45 ±0.05^{a}	1.26 ±0.02^{b}	Ns	*	Ns
PUFA	**26.89 ±0.29**	**26.27 ±0.47**	**26.88 ±0.33**	**26.16 ±0.28**	**25.97 ±0.19**	**25.21 ±0.41**	**26.02 ±0.44**	**25.62 ±0.53**			
Oleic acid	39.20 ±1.14^{a}	38.74 ±1.21^{b}	39.26 ±1.17^{a}	39.14 ±0.16^{b}	38.48±0.24^{a}	38.11 ±1.11^{b}	38.81 ±0.85^{a}	38.52 ±1.22^{b}	Ns	*	Ns
Myristoleic acid	0.29 ±0.07^{a}	0.28±0.03^{b}	0.32 ±0.01^{a}	0.31 ±0.04^{b}	0.24 ±0.07^{a}	0.22 ±0.09^{b}	0.27 ±0.05^{a}	0.26 ±0.08^{b}	Ns	*	Ns
Benzoic acid	0.07 ±0.01^{a}	0.04 ±0.03^{b}	0.08 ±0.05^{a}	0.05 ±0.02^{b}	0.05 ±0.01^{a}	0.03 ±0.02^{b}	0.06 ±0.04^{a}	0.05 ±0.01^{b}	Ns	*	Ns
Eicosenoic acid	0.84 ±0.33^{a}	0.81 ±0.17^{b}	0.83 ±0.25^{a}	0.85 ±0.16^{b}	0.82 ±0.20^{a}	0.78 ±0.14^{b}	0.83 ±0.19^{a}	0.80 ±0.15^{b}	Ns	*	Ns
Palmitoleic	2.45 ±0.03^{a}	2.25 ±0.06^{b}	2.49 ±0.23^{a}	2.35 ±0.07^{b}	2.21 ±0.05^{a}	2.14 ±0.04^{b}	2.22 ±0.01^{a}	2.18 ±0.05^{b}	Ns	*	Ns
MUFA	**42.85 ±0.32**	**42.12 ±0.30**	**42.98 ±0.34**	**42.70 ±0.09**	**41.80 ±0.11**	**41.28 ±0.28**	**42.19 ±0.23**	**41.81 ±0.31**			
UFA	69.74 ±0.61	68.39 ±0.77	69.86 ±0.67	68.86 ±0.37	67.77 ±0.30	66.49 ±0.69	68.21 ±0.67	67.43 ±0.84	Ns	*	Ns
PUFA/MUFA	0.64 ±0.09	0.63 ±0.10	0.63 ±0.10	0.62 ±0.02	0.63 ±0.02	0.62 ±0.12	0.63 ±0.10	0.62 ±0.16	Ns	*	Ns
UFA/SFA	2.30 ±0.12	2.16 ±0.14	2.31 ±0.13	2.21 ±0.09	2.10 ±0.06	1.98 ±0.11	2.15 ±0.15	2.07 ±0.19	Ns	*	Ns

*^{ab}Mean values under the same category across column that bear different superscript letters are significantly different, Ns = P > 0.05, * = P≤ 0.05, SE = standard error of mean, Ab=Abobo, GKz= GambellaKetemaZuria, It= Itang, and La= Lare chicken strains. M= male, F= female, CS= chicken strain, S= sex, FA= fatty acid.*

Table 4. Correlation of blood serum and meat fatty acid profiles in different chicken strains

Profiles	HDL	LDL	TG	TC	SFA	MUFA	PUFA	UFA	PUFA/MUFA	UFA/SFA
HDL	1.00									
LDL	-0.75	1.00								
TG	-0.85	0.97	1.00							
TC	-0.85	0.98	0.99	1.00						
SFA	-0.60	0.94	0.91	0.87	1.00					
MUFA	0.68	-0.93	-0.92	-0.88	-0.97	1.00				
PUFA	0.49	-0.92	-0.87	-0.84	-0.98	0.94	1.00			
UFA	0.60	-0.94	-0.91	-0.87	-0.99	0.97	0.98	1.00		
PUFA/MUFA	-0.99	0.76	0.86	0.85	0.62	-0.71	-0.50	-0.62	1.00	
UFA/SFA	0.61	-0.95	-0.91	-0.87	-0.99	0.99	0.98	0.99	-0.62	1.00

UFA/SFA = Unsaturated Fatty Acid Ratio Saturated Fatty Acid, PUFA/MUFA = Poly Unsaturated Fatty Acid ratio Monounsaturated Fatty Acid, SFA = Saturated Fatty Acid, UFA= Unsaturated Fatty Acid, PUFA= Poly Unsaturated Fatty Acid, MUFA= monounsaturated Fatty Acid, LDL = Low Density Lipoprotein, HDL= High Density Lipoprotein, TG = Triglycerides, TC = Total Cholesterol

slightly agree with some previous studies which indicated that MUFA had significant affect among genotypes and within sex[20,21]. MUFA significantly (P<0.05) affected the Fast-growing (38.00), Medium-growing (34.80) and Slow-growing (28.70) chickens[22]. The current findings are in line with Benabdelmoumene *et al.,*[19] who reported that female might have superior bioactivity than male except effect of isoproterenol.

The mean values of UFA in Ab, GKz, It, and La chicken strains had significantly lower (P≤0.05) in male (68.39 ±0.77, 68.86 ±0.37, 66.49 ±0.69, and 67.43 ±0.84) than female (69.74 ±0.61, 69.86 ±0.67, 67.77 ±0.30, and 68.21 ±0.67) chicken strains respectively.The current findings are concurrent with some previous studies which stated that the UFA might be varied between sex due to globulin[12], Albumin[23,24,25] and Desaturases[16,21]. The mean values of the PUFA/MUFA were non-significantly different (P≤0.05) among different chicken strains and sexes of Ab, GKz, It, and La female (0.64 ±0.09, 0.63 ±0.10, 0.63 ±0.02, and 0.63 ±0.10) and male (0.63 ±0.10, 0.62 ±0.02, 0.62 ±0.12, and 0.62 ±0.16) chicken strains respectively.In agreement with the current results, a previous study reported that PUFA/MUFA of meat with ratio less than 0.40:1 could affect the dietary balance[26].

The mean values of the UFA/SFA were non-significantly different (P≤0.05) among different chicken strains and sexes of Ab, GKz, It, and La female (2.30 ±0.12, 2.31 ±0.13, 2.10 ±0.06, and 2.15 ±0.15) and male (2.16 ±0.14, 2.21 ±0.09, 1.98 ±0.11, and 2.07 ±0.19) chicken strains respectively. The current findings were in acceptable range as the UFA/SFA of meat Having ratio 4:1 could affect the dietary balance[22] and oxidative effect by isoproterenol[15].

The correlation between blood serum and meat fatty acid profiles in different chicken strains

The Correlation coefficient (r) between blood serum contents and meat fatty acid profiles of different chicken strains are illustrated in Table 4. The HDL was strongly and positively (P≤0.01) correlated with the MUFA, PUFA, UFA, and UFA/SFA (r = 0.68, 0.49, 0.60, and 0.61) respectively, but moderately and negatively (P<0.01) correlated with the LDL, TG, TC, SFA, and PUFA/MUFA (r= -0.75, -0.85, -0.85, -0.60, and -0.99) respectively. LDL was strongly and positively correlated (P≤0.01) with the TG, TC, SFA, and PUFA/MUFA (r = 0.97, 0.98, 0.94, and 0.76) respectively, but strongly and negatively correlated (P<0.01) with the MUFA, PUFA, UFA, and UFA/SFA (r=-0.93, -0.92, -0.94, and -0.95) respectively.

The serum lipid profile of broilers has positive correlation with the muscle lipid[27]. There was positive and significant (P<0.05) correlation between abdominal fat weight and serum cholesterol content of each Rugao (r=0.440) and Anka (r=0.089) chicken genotypes[8]. Significant (P<0.05) positive correlations (r=0.669) for white and (r=0.240) brown chickens were determined between serum TC level and egg production and correlation between serum lipids and egg lipids could be significantly varied[25,26]. However, serum cholesterol was negatively correlated with egg cholesterol in white and brown chickens[26]. The serum lipid profile of chickens had positive correlation with the egg lipid and could direct to more research in producing low cholesterol eggs that might have market implication[11].

The TG was strongly and positively correlated (P<0.01) with TC, SFA, and PUFA/MUFA (r= 0.99, 0.91, and 0.86) respectively, but moderately and negatively correlated at (P<0.01) with the MUFA, PUFA, UFA, and UFA/SFA (r=, -0.92, -0.87, -0.91, and -0.91) respectively.

TC was highly and negatively correlated (P<0.01) with the MUFA, PUFA, UFA, and UFA/SFA (r= -0.88, -0.84, -0.87, and -0.87) respectively, but highly and positively correlated (P<0.01) with the SFA, and PUFA/MUFA (r= 0.87, and 0.85) respectively.TG had positive correlation with fat accumulation in meat of chickens[15]. The SFA was highly and negatively correlated (P<0.01) with MUFA, PUFA, UFA, and UFA/SFA (r=-0.97, -0.98, -0.99, and -0.96) respectively, but moderately and positively correlated (P<0.01) with the PUFA/MUFA (r= 0.62) respectively.

Increase in the levels of total cholesterol, LDL, and triglyceride was correlated with saturated fatty acids while increase in the LDL level was associated with UFA[28]. PUFA/SFA ratio less than 0.45 in chicken meats had been reported unhealthy for consumers[29]. Fast growing chicken strains had higher fatty meats than slow growing strains[25,29]. Breast and thigh meats of slow growing chickens had lower composition of lipids than fast growing chickens[22].

The MUFA was highly and positively correlated (P<0.01) with the PUFA, UFA, and UFA/SFA (r= 0.94, 0.97, and 0.99) respectively, but moderately and negatively correlated (P<0.01) with the PUFA/MUFA (r= -0.71) respectively. The PUFA was highly and strongly correlated (P<0.01) with the UFA, and UFA/SFA (r= 0.98, and 0.99) respectively, but slightly and negatively correlated at (P<0.01) with the PUFA/MUFA(r=-0.50). PUFA and PUFA n-6 were significantly (P<0.01) higher in both thigh and breast meat of slow growing than fast growing chickens[22,23] and slow growing chickens could be better sources of desirable FA than fast growing chickens[30].

The UFA was highly and positively correlated at (P <0.01) with the UFA/SFA (r= 0.99) and slightly and negatively correlated at (P <0.01) with the PUFA/MUFA (r= -0.62) respectively. The PUFA/MUFA was moderately and negatively correlated (P <0.01) with the UFA/SFA (r= -0.62). Padovana meat had significantly (P<0.05) higher UFA/SFA and lower n-6/n-3 than Polverarachickens[31]. Females had better n-6/n-3 than males in both Padovana and Polverara chickens[31]. The lowest content of lipids and highest content of UFA were found in meats of naked neck chickens than others[19].

CONCLUSION

HDL concentrations were higher in female than male in the different chicken strains studied. However, LDL, TG, and TC concentrations were significantly higher in male than female of different chicken strains studied. From the contents of SFAs, all investigated acids (Palmitic, Myristic, Decanoic, Pentadecanoic, Margaric, Stearic, and Tetradecylic) were non-significantly different between different chicken strains studied. However, there were significant differences between both sexes of different chicken strains studied. MUFAs (Benzoic and Eicosenoic) had lower concentration than, the Oleic acid, Myristoleic acid, and Palmitoleic acids from all the different chicken strains studied. The mean values of UFA in different chicken strains studied were significantly lower in male than female chicken strains. The mean values of the PUFA/MUFA and UFA/SFA were non-significantly different among different chicken strains and sexes studied. The HDL was strongly and positively correlated with the MUFA, PUFA, UFA, and UFA/SFA.

The TC was highly and negatively correlated with the MUFA, PUFA, UFA, and UFA/SFA. The SFA was highly and negatively correlated with MUFA, PUFA, UFA, and UFA/SFA. The UFA was highly and positively correlated with the UFA/SFA and slightly and negatively correlated with the PUFA/MUFA. The blood serum contents, and meat fatty acid profile varied between the sexes of the chicken strains studied. Level of serum contents can be transferred into human being. Chicken products with higher level LDL, TG, TC and SFA might have human health problems. Therefore, the feed manipulation may be tried to improve lipids in chicken products to manage the health problems to human being. Finally, it could also be hot and interesting issues for further investigation in different studies.

Competing Interests

The authors declare that there is no conflict of interests.

ACKNOWLEDGMENTS

The authors express their appreciation to the ILRI (International Livestock Research Institute, ACGG program) for sponsoring the first author and cover all required research fund. And author's appreciation goes to Addis Ababa University College of veterinary medicine and agriculture of thematic research (IPP) and the authors would like to thanks to Gambella University for sponsoring the first author to study leave.

REFERENCES

Adele M, S. Federico, C. Cesare, R. Alessandra, M. Paolo, F. Achille. (2016). Influence of genotype and feeding on chemical composition of organic chicken meat, Italian Journal of Animal Science.:https://doi.org/10.4081/ijas.2009.s2.766

Aline G, M. Marcel, l. Juliana, A. Rodrigo, B. Fabio, A. Pedro, B. Hirasilva. (2020). Lipid Assessment, Cholesterol and Fatty Acid Profile of meat from broilers raised in four different rearing systems.: DOI: 10.1590/0001-3765202020190649

Alrekabi M, N. Ali, I. Aldulaimi, O. Alobaidi, K. Aldulaimi, H. Alziadi. (2018). The effect of sex and slaughter age in some blood traits of broiler chicks Ross 308. International Conference Food and Agricultural Sciences, Iran.: https://www.researchgate.net

Antonella D, T. Giulia, B. Gabriele, C. Marco. (2019). Meat quality of male and female Italian Padovana and Polverara slow-growing chicken breeds, Italian Journal of Animal Science.:https://doi.org/10.1080/1828051X.2018.1530963.

Kral I, Suchy P (2000). Hematological studies in adolescent breedingcocks. Acta. Vet. Brno. 69: 189 – 194: DOI:10.2754/avb200069030189

Benabdelmoumene D, B. Benakriche, F. Beghdadi, M. Halbouche. (2016). Effects of Genotype and Sex on Lipid Oxidation and Fatty Acid Profile of Chicken Breast Meat, Pakistan Journal of Nutrition, ISSN 1680-5194.:DOI: 10.3923/pjn.2016.187.193, https://www.researchgate.net

Brenes, A. and Roura, E. (2010) Essential Oils in Poultry Nutrition: Main Effects and Modes of Action. Animal Feed Science Technology, 158, 1-14.:https://doi.org/10.1016/j.anifeedsci.2010.03.007

Cesare C, D. Alessandro, M. Cecilia, Martina P. (2006). Comparison of two chicken genotypes organically reared: oxidative stability and other qualitative traits of the meat, Italian Journal of Animal Science.: DOI:10.4081/ijas.2006.29

Fatimah A, K. Nagam, K. Ahmed (2020). A Comparative Study of Some Biochemical Blood Characteristics of Six Lines of Iraqi Local Female Chickens, A multifaceted review journal in the field of pharmacy, Iraq.:DOI:10.31838/SRP.2020.10.161

Hassan H, G. H. Chen, K. H. Wang, B. C. Li, D. M. Mekki, J. T. Shu, H. P. Ju. (2007). Relation between Abdominal Fat and Serum Cholesterol, Triglycerides, and Lipoprotein Concentrations in Chicken Breeds Turk. J. Vet. Anim. Sci.; 31(6): 375-379:https://dergipark.org.tr

Ibrahim A, J. Aliyu, N. Wada, A. Hassan (2012). Effect of sex and genotype on blood serum electrolytes and biochemical parameters of Nigerian indigenous chickens. Iranian Journal of Applied Animal Science, 2, 361-365.: www.ijas.ir

Imasuen J, C. Otoikhian. (2012). Preliminary Investigation on the Relationship between Blood Lipid Profile and Egg Lipid Profile in Different Breeds of Layers.: http://www.ijpmbs.com.

Kalita D, R. Sultana, M. Roy, K. Bharali. (2018). Comparative study of certain biochemical profile of broiler and indigenous chicken of Assam, Approaches

in Poultry, Dairy and Veterinary Sciences, 2, 175-177.:https://crimsonpublishers.com

Khawaja T, S. Khan, N. Mukhtar, A. Ali, T. Ahmed, A. Ghafar. (2012). Comparative study of growth performance, egg production, egg characteristics and biochemical parameters of Desi, Fayoumi and Rhode Island Red chicken, Journal of Applied Animal Research, 273-283.:https://doi.org/10.1080/09712119.2012.672310

K.D. Adeyemi, A.O. Olorunsanya (2012). Comparative Analysis of Phenolic Composition andAntioxidant Effect of Seed Coat Extracts of Four Cowpea(Vignaunguiculata) Varieties on Broiler Meat. Iranian journal of applied animal science.:www.ijas.ir.

Lenka T, H. Peter, C. Juraj, B. Marek, P. Adriana. (2016). Fatty acids profile of breast and thigh muscles of broiler chickens fed diets with propolis and probiotics.:DOI: 10.5513/JCEA01/17.4.1828

Madalena L, C. Joana, M. Claudia, P. Susana, J. Rui I. Carolino. (2020). A comparison between the quality of eggs from indigenous chicken breeds and that from commercial layers, Poultry Science 99:1768–1776.:https://doi.org/10.1016/j.psj.2019.11.023

Mahiza M, H. Lokman, E. Ibitoye. (2021). Fatty acid profile in the breast and thigh muscles of the slow and fast-growing birds under the same management system, Tropical Animal Health and Production under exclusive license to Springer Nature.:DOI: 10.1007/s11250-021-02777-1

Masud A., O. Mohammad, U. Syeda, S. Mohammad. (2020). Broiler and Indigenous Chickens: A Comparison through Biochemical Parameters.:https://EconPapers.repec.org/RePEc:pkp:ijosar:v:7:y:2020:i:4:p:228-233:id:307

Ozlem K, S. Tarkan, O. Mukremin, Y. Akın, O. Bulent. (2020). Changes in serum biochemical and lipid profile, and fatty acid composition of breast meat of broiler chickens fed supplemental grape seed extract, Turkish Journal of Veterinary and Animal Sciences.:http://journals.tubitak.gov.tr/veterinary/.

Pampori Z, Iqbal, S. (2007). Hematology, serum chemistry and electrocardiographic evaluation in native chicken of Kashmir. International Journal of Poultry Science, 6(8), 578-582. Available at: https://doi.org/10.3923/ijps.2007.578.582

Ramesh A, M. Anand, B. Shambulingappa, K. Ananda. (2009). Study of Lipid Profile and Production Performance in Layers as Influenced by Herbal Preparations Abana and Garlic Paste, Veterinary World, 426-428.:http://www.veterinaryworld.org

Rasheed S, O. Olusegun. (2017). Influence of age and strain on hematological and blood biochemical indices in broiler chickens reared in derived Savanna environment of Nigeria. American Journal of Biology and Life Sciences, 5, 34-38.: https://www.researchgate.net

Russel P, P. Elsje, H. Louw. (2014). Comparison of Production Parameters and Meat Quality Characteristics of South African Indigenous Chickens, Stellenbosch University.: http://scholar.sun.ac.za

Sanchai J, K. Autchara, W. Michael. (2008). Carcass and meat characteristics of male chickens between Thai indigenous compared with improved layer breeds and their crossbred.:DOI:10.5194/AAB-51-283-2008

SAS., 2008. SAS® 9.1 Provides New Product-Specific Release Numbers. SAS Products and Solutions. https://bit.ly/2VDiPfw

Sharadendu B, S. Maneshwar (2019). Serum lipids and lipoproteins: A brief review of the composition, transport and physiological functions, International Journal of Scientific Reports.:DOI: http://dx.doi.org/10.18203/issn.2454-2156.IntJSciRep20194253

Varshil M, B. Kavya. (2017). Lipids and its Metabolism, Journal of Cardiology and Cardiovascular Therapy, Review Article, Santosh Medical College, India.:DOI: 10.19080/JOCCT.2017.04.555635

Wang, K, H. Musa (2007). The impact of obesity on serum biochemical components, Journal of Cell and Animal Biology, pp. 087-091.:https://doi.org/10.5897/JCAB.9000156

Wilhelm P, L. Julio, B. Marko, C. Maria, M. Ali, S. Andrej, E. Suzanne. (2012). Lipoproteins in Drosophila melanogaster Assembly, Function, and Influence on Tissue Lipid Composition, PLoS Genet: e1002828.:https://doi.org/10.1371/journal.pgen.1002828

Wood JG, et al. (2004)Sirtuin activators mimic caloric restriction and delay ageing in metazoans. *Nature* 430(7000):686-9: DOI: 10.1038/nature02789