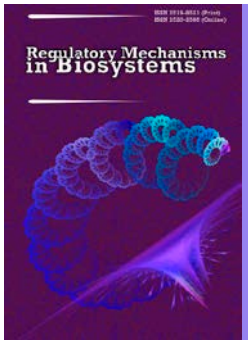

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Dietary energy source affecting fat deposition mechanism, muscle fiber metabolic and overall meat quality

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A study was conducted to investigate the effect of two dietary energy sources, soy bean oil, and sucrose on regulatory mechanisms of meat preservation. Twenty one day-old Hubbard commercial broilers were randomly allocated into two dietary treatment groups with six replicates per treatment, and four broilers per replicate. All birds were coded for the influence of energy source: fat based diet (FD), and sugar based diet (SD). Formulated grower diets were isonitrogenous and isocaloric. The chickens were slaughtered and then boneless, skinless ground chicken tight meat was prepared. Both raw and cooked meats were analyzed for lipid and protein oxidation, and sensory panel evaluation. In addition, meat from the small muscles of the raw thigh was used to evaluate other meat quality characteristics. Proximate analyses showed no significant differences between both dietary treatments on protein, ash and moisture percentage values. Meat samples of the group that was fed FD showed higher significant values of both TBARS and total carbonyl at day 7 of storage time. However, samples of the second group (Fed SD) showed lower values of both ultimate pH and water separation % using raw thigh meat. The effect of FD treatment on the meat composition appeared clearly especially on fat percentage content. In addition, meat samples obtained from chickens fed SD showed better significant values of the overall acceptability attribute. According to the current findings, sucrose could be an excellent alternative to oil in dietary broilers which improved the meat preservation bio-system, and post-mortem storage stability.

Keywords: poultry; sucrose; thigh meat; lipid oxidation; protein oxidation

Introduction

Oil is considered the richest energy source among other nutrients (oil contains 2.25 times the energy content of carbohydrate and protein) and thus is used to increase caloric density of diets fed to broilers (Waheed et al., 2004). In addition, oil has been reported to increase the absorption of fat soluble vitamins, increase palatability of the feed and thus feed intake, reduce the passage rate of digesta, which allows higher nutrient absorption (Baiao and Lara, 2005). However, potential hazard is associated in feeding high fat diets if handled incorrectly, one such problem being oil rancidity (Shermer, 1990), this leads to reduction in caloric density of broiler diets. In addition, it may produce off flavours which can reduce broiler feed intake, depress growth, and eliminate the body reservoir of antioxidants (Shermer, 1990; Baiao and Lara, 2005; Tavarez et al., 2011). The harmful influence of oil rancidity brings direct economic losses to broiler farmers and can negatively affect carcass quality (Alao and Balnave, 1984; Zelenka et al., 1997; Crespo and Esteve Garcia, 2002). Therefore, the source of dietary lipid may affect total body fat deposition, fatty acid composition, and overall meat quality (Ellis and Mckeith, 1999; Baiao and Lara, 2005; Fuad and El-Senousey 2014). In addition, it can influence consumer perception, health, and indirectly their food safety (Savell and Cross, 1988). Fatty acid profile and freshness of meat carcass are highly affected and correlated with the fat deposition mechanism. However, the type and degree of polyunsaturated fatty acid is also as important as the total amount of fat deposition in meat, which makes thigh meat more susceptible to lipid per-oxidation compared to other carcass muscles (Min et al., 2008). In addition, cooked meat is more affected by free radicals and oxidized faster than raw meat (Gray et al., 1992; Lee et al., 2003). Thus, initial carcass lipid and protein oxidation level can influence storage stability of chicken meat, especially after thermal processing. Other meat quality characteristics, such as colour, texture, and water holding capacity can also be influenced by the oxidation mechanism and their free radicals formation (Jensen et al., 1997; Du et al., 2000). A sugar (sucrose) has been reported as a better energy source than starch and could be replaced, partially, by fat in poultry diet (Hashim et al., 2013; Hussein et al., 2016). Sucrose is a disaccharide that can be easily digested by poultry (Wang, 2014) and has been reported to have a higher AMEn than glucose (3750 vs. 3330 kcal/kg) (Leeson and Summers, 2001). In avian species, glucose has been reported to have a sparing effect on amino acid oxidation (Yadalam, 2005). Furthermore, excess of glucose is stored as glycogen or directed for de novo lipogensis in the liver (Hermier, 1997). In addition, glucose has a higher heat increment compared to lipid. Thus, feeding sucrose may reduce energy delivery to broilers compared to lipid. Reducing energy level in broilers have been reported to decrease total body fat deposition by mechanisms related to decrease in the activity of enzymes linked to hepatic lipogenisis (Tanaka et al., 1983; Fuad and El-Senousey, 2014). Furthermore, change in the dietary energy source will affect the metabolic of muscle fiber type (type I and II), lactic acid accumulation, and postmortem muscle pH (Aalhus et al., 2009). Lipid in broilers accumulates mainly in the form of polyunsaturated fatty acids (PUFA), which make it more susceptible to oxidative deterioration during storage (Ahn et al., 2002; Min et al., 2008). In modern broiler strains, Choct et al. (2013) reported that broilers contain up to

20% fat and more than 85% of this fat has no physiological function and thus, reducing fat component in broilers may enhance carcass stability and quality after slaughtering. The aim of current study was to investigate the effect of replacing soy bean oil in broiler grower diet with sucrose on regulatory mechanisms of meat preservation.

Materials and methods

1. Birds and diet formulation. Forty eight broilers were raised for 21 days (from 21 to 42 days old) according to general commercial husbandry practices. This experiment was reviewed and approved by the Department of Animal Production, and all chickens were checked and their health and welfare cleared by veterinarians. Two groups of 48 broilers were randomly assigned into two dietary treatments (each treatment contains 6 replicates and 4 broilers per replicate). During the experimental period, all birds were raised in floor cages and were offered one of two dietary treatments and water ad lib by using trough feeders and drinkers. The two dietary treatments were formulated to be iso-calroic and iso-nitrogenous. Dietary treatments were coded for the influence of energy source: Fat based diet (FD) and Sugar based diet (SD). The ingredients and chemical composition of experimental diets are shown in Table 1.

Table 1
Ingredients (%) and chemical composition (%)
of fat based diet (FD) and Sucrose based diet (SD)

Ingredients (%)	FD	SD
Corn	50.04	63.62
Soya bean meal	27.93	16.55
[a]Broncon concentrate	10.50	11.49
NaCl	0.19	0.19
Limestone	1.75	0.89
[b]Vit. and mineral premix	0.10	0.10
L-Lysine.HCL (78%)	0.10	3.36
DL-Methioine	0.23	0.40
Degamed soybean oil	5.27	0.00
Monocalcium phosphate	0.41	0.01
Sucrose	0.00	3.30
[c]Antifungi	0.10	0.10
Wheat bran	3.39	0.00
[d]Chemical composition (%)		
ME, Kcal/kg	3050	3050
Crude protein	21.00	21.00
Crude fibre	3.93	3.10
Ca	1.30	0.90
Non phytate phosphorus	0.46	0.35
Methioine	0.67	0.80
Lysine	1.25	4.25
Cyctein	0.22	0.20
Na	0.22	0.23
Cl	0.15	0.15

Note: [a] – Brocon Concentrate® (Wafa, B. V., Alblasserdam, Holland); [b] – vitamin premix provided per kilogram of premix: Vitamin A, 700,000 IU; vitamin D_3, 150,000 IU; vitamin E, 75 mg; vitamin B_1, 100 mg; vitamin K, 175 mg; vitamin B_5, 600 mg; manganese oxide, 4000 mg; ferrous sulphate, 9000 mg; zinc oxide, 6000 mg; magnesum oxide, 2500 mg; potassium iodide, 70 mg; sodium selenite, 125 mg; copper sulphate, 100 mg; cobalt sulphate, 50 mg; dicalcium phosphate, 7000 mg; sodium chloride, 10000 mg; [c] – mold inhibitor for animal feed (Kemin Industries, U.S.A); [d] – calculated based on analyzed values of feed ingredients (feed composition tables) from poultry NRC (1994).

2. Sample preparation. On day 42, the broilers were slaughtered (Mu'tah University, Agriculture Collage: Department of Animal Production-farm facilities) using standard guidelines of poultry slaughterring in Jordan (Ministry of Agriculture) and under the supervision of veterinarians. The chicken carcasses were chilled in ice water for 2h and drained in a laboratory cold room, and the muscles (thigh meat) were separated from the carcasses at 24h after slaughtering. Boneless thigh muscles were cleaned, skins removed, external fats trimmed off, vacuum packaged in oxygen impermeable bags, and stored at –18 °C in a freezer until used for further analysis. Thigh meat was selected for this study analysis because of its high fat content and myoglobin pigment, and its mixture of muscle fiber (different metabolic) type. Separated raw meat samples were stored for 7 days at 4 °C and were used to evaluate meat quality characteristics. Different parameters were measured to evaluate the effect of dietary energy source on muscle fiber metabolic, fat deposition mechanisms indirectly; and on meat preservation. For stability analysis (lipid and protein oxidation) frozen meats were thawed in a walk-in cooler (4 °C), ground twice through 8 and a 3 mm plates (Moulinex, Type DKA1, France), respectively, before use. Meats of each treatment replicate (n = 6) were ground and homogenated as a single batch, and subdivided into 50 g of ground meat patties. The prepared raw meat patties were packaged in oxygen permeable bags (Size: 11 x 25 cm, Future for Plastic Industry, Al-Moumtaz bags, Co. LTD, Jordan) in a cold room at 4 °C for up to 7 days for quality analysis. In the study related cooked-patties, the raw meat was placed in oxygen impermeable vacuum plastic-bags (Ehsan & Tahssin Baalbaki Co, Bayader Wadi Al-Seer, Amman, Jordan), then cooked in-bag in a 90 °C water bath (Memmert, WNB 14; GMbH + Co. KH, D-91107 Schwabach, Germany). Samples were moved out when the internal temperature of the meat patties was 75 °C. After cooling, the cooked meat patties (50 g) was placed inside new oxygen-permeable bags, stored at 4 °C, and analyzed for lipid (TBARS) and protein oxidation at three time intervals. Same preparation procedure was done for all sensory analysis treatment samples. However, the ground chicken (raw thigh) meat patties were stored at 4 °C up to 4 days before cooking, and for each evaluation session.

3. Thiobarbituric acid-reactive substances (TBARS) measurement. Briefly, the TBARS values in the meat samples were measured according to the method described by Ahn et al. (1998). The TBARS values were calculated based on malonaldehyde (MDA) stander carve (TEP standard solution) and reported as mg of MDA per kg of meat.

4. Protein oxidation (total carbonyl). Protein oxidation was determined by the method of Lund et al. (2008) with minor modifycations as described by Al-Hijazeen et al. (2016). In addition, carbonyl content was recorded as nmol/mg protein using absorption coefficient of 22,000/M·cm as described by Levine et al. (1994).

5. Proximate analysis. Proximate analysis was determined for all treatment samples according to the method of AOAC (2003). Moisture, crude protein, fat and ash (%) were analyzed using thigh meat samples. Samples of each treatment were selected randomly and the averages of 6 sub-samples (2 sample/replicate) were statistically analyzed.

6. pH of raw thigh meat. Acidity of the chicken raw meat samples was measured using a pH meter (PL-600, pH/mV/Temp Meter, Taiwan) after homogenizing the 1.0 g samples with 9 ml deionzed distilled water (DDW) (Sebranek et al., 2001).

7. Cooking loss %. Chicken thigh meat samples (30 g) were weighed and packaged in oxygen impermeable vacuum bags. The meat was cooked at a constant temperature using pre-heated water bath (Memmert, WNB 14; GMbH + Co. KH, D-91107 Schwabach, Germany) to the internal temperature of 80 °C for 90 min for the maximum water loss expected (Murphy and Marks, 2000). After cooking, all meat samples were cooled in a cold water bath until the internal temperature of the samples reached 20 °C, then water blotted or purged until the samples became dry. The cooking loss percentage was calculated as percent weight reduction of the cooked sample compared to the raw meat sample using the following equation:

$$\text{Cooking loss \%} = \frac{100\times (\text{Weight of raw meat} - \text{Weight of cooked meat})}{(\text{Weight of raw meat})}$$

8. Water separation (Centrifuge method). Samples of 20 g (meat/water mixture) were placed into 50 mL centrifuged tubes to measure their separated water as described by Sebranek et al. (2001) with minor modification. The samples were placed in tubes then centrifuged at the speed of 10,000 rpm for 20 minutes (High Speed Centerfuige, TG16G, Hunan Kaida, China). After centrifugation, the excess water was decanted and tubes were re-weighed. Water separation percentage (expression of water holding ability) was calculated as ratio of centrifuged water to the original sample weight. This method measures how strongly water is bound or held by meat proteins.

9. Sensory evaluation. Trained sensory panels were used to evaluate the sensory characteristics of the ground chicken thigh meat.

Sensory panels evaluated the colour, aroma, and overall acceptability of both raw and cooked meat. Two different treatments were prepared with the same method described in the oxidation analysis (lipid and protein oxidation). The meat was refrigerated at 4 ºC for three days before each evaluation session. Ten trained panelists (Muta'h University, students and staff), participated in each session. The evaluations were done twice after three days of storage time at 4 ºC. For training, 3 one-hour sessions were held using commercial ground chicken meat to develop descriptive terms for the desired attributes. The raw meat was evaluated for colour (redness), visual fat, oxidative odour, and overall acceptability. On the other hand, cooked meats were evaluated for cooked chicken odor, oxidative odour, sulfur odour, and overall acceptability.

All attributes were measured using a line scale without numbers (numerical value 9 units) with graduation from 0 to 9. For example, overall acceptability; where 9 represented extremely desirable, and 0 represented extremely undesirable (9 – extremely desirable, 8 – very, 7 – moderate, 6 – slightly, 5 – neither nor, 4 – slightly undesirable, 3 – moderately undesirable, 2 – very undesirable, and 1 – extremely undesirable). Similar terminology (e.g detectable or undetectable) underline was used for the other attributes. Cooked and raw meat evaluation sessions were done on separate days to decrease any variability.

Refrigerated (4 ºC) samples were evaluated by the panelists for each treatment. The panelist was served 1 glass vial, 20 ml volume, of each treatment to evaluate colour and odor of raw thigh meat. All ground meat samples were packaged in oxygen permeable bags before the evaluation session. The panelists were asked to evaluate the ground meat patties (color) and open the vials to evaluate odour. The raw meat samples of 10 g each were placed in small vials (20 mL) capped with a septum in order to evaluate odor attributes. All sample vials were labeled by a three digit number selected randomly. For cooked meat, samples (4 g) at 0 day of cooking were placed in a three digit coded 20 mL sample vial and capped with a septum. Panelists were asked to smell samples in random order and record the intensity of odor or overall acceptability on the scale line.

10. Statistical analysis. Data were analyzed using statistical analysis of SAS program, version 9.3 (2012). For all analysis, the student t test at 5% level of significance was used to compare the measured means between the two treatments. Mean values and standard deviation of the means (Mean ± SD) were reported.

Results and discussion

Proximate analysis. In order to evaluate the effect of adding different dietary energy sources on the meat preservation system, it is important to analyze meat composition. There were no significant differences ($P > 0.05$) between both treatments of their moisture, protein, and ash percentage (Table 2). However, the moisture values were numerically lower using FD treatment samples. This may be due to higher ($P < 0.05$) value of fat in their lean meat tissues (Table 2).

Table 2
Proximate analysis of raw chicken thigh meat (Mean ± SD, n = 6)

Treatment	Fat %	Protein %	Ash %	Moisture %
FD	7.23 ± 0.10	21.4 ± 0.76	0.98 ± 0.017	70.4 ± 0.82
SD	6.23 ± 0.27	21.6 ± 0.99	0.98 ± 0.017	71.2 ± 1.14
P-value	< 0.0001	0.7993	1.0000	0.1613

Although both dietary treatments were formulated to be isocalric and isonitrogenous, Glucose/sugar has a higher heat increment compared to lipid after metabolism (De Groote et al., 1971). Thus, feeding sucrose may reduce net energy delivery to the broilers compared to lipid. Reducing energy level in broilers has the result of decreasing total body fat deposition (Tanaka et al., 1983). Furthermore, broilers fed SD had a lower feed intake (Data were not shown). Lower feed intake through feed restriction has been reported to decreased energy delivery and thus body fat accumulation (Rezaei et al., 2010; Chen et al., 2012; Wu et al., 2012). This significant difference in fat meat should be the major factor which can affect meat quality and their stability during storage time. However, low fat content may affect negatively some eating quality characteristics (tenderness, juiciness, odor, and flavor) and consumer acceptance (Savell and Cross, 1988; Ellis and Mckeith, 1999).

Lipid oxidation. There were no significant differences ($P > 0.05$) between TBARS values (raw and cooked thigh meat) of both FD and SD treatment at day 0 (Table 3).

Table 3
TBARS* values (mg/kg) of ground chicken thigh meat at different storage time (Mean ± SD; n = 6)

Time	FD	SD	P-value
	Raw		
Day 0	0.232 ± 0.029	0.247 ± 0.047	0.5408
Day 4	0.968 ± 0.069	0.289 ± 0.028	< 0.0001
Day 7	2.495 ± 0.042	1.244 ± 0.015	< 0.0001
	Cooked		
Day 0	1.207 ± 0.510	1.064 ± 0.143	0.5350
Day 4	3.537 ± 0.182	1.832 ± 0.652	0.0010
Day 7	7.416 ± 0.234	5.198 ± 0.869	0.0011

Note: * – TBARS value in mg malonaldehyde/kg meat.

This was in agreement with the previous research studies conducted on ground chicken meat (Rababah et al., 2006; Chouliara et al., 2007; Al-Hijazeen et al., 2016). In addition, TBARS values of raw meat samples obtained from FD treatment were significantly ($P < 0.05$) higher at day 4 of storage time. Furthermore, TBARS values of FD treatment were significantly ($P < 0.05$) lower using raw meat at day 7 of storage time. This may be due to the higher fat content and fatty acid profile in meat samples of broilers that were fed FD. However, initiation and propagation steps (autoxidation reaction) in lipid oxidation mechanism are highly affected by fatty acid saturation and their profile sequences (Ahn et al., 2009). In addition, the TBARS values using cooked meat were significantly ($P < 0.05$) higher for FD treatment compared to SD treatment. Generally, the TBARS values in cooked chicken meat were higher than raw meat, and the signifycances could be better if cooked meat was used (Min et al., 2008; Ahn et al., 2009). This may be due to the low free iron content and high ferric ion reducing capacity in fresh meat (Min et al., 2008). In addition, the oxidative change is usually higher in cooked meat because enzymes denatured, iron ion released to the extracellular compartment, membrane bi-layers damaged, and phospholipids were oxidized faster during cooking (Gray et al., 1996). So the TBARS values of SD treatment increased during storage time with a lower rate compared to the FD treatment. However, farther research studies are needed to investigate the mechanism of fatty acid deposition using different dietary energy.

Protein oxidation. There were no significant differences ($P > 0.05$) of the total carbonyl (nmol/mg protein) values using both dietary treatments at day 0. However, these values of FD treatment were significantly higher ($P < 0.05$) at days 4 and 7 of storage time using both raw and cooked meat (Table 4).

Table 4
Effect of using different dietary energy sources on protein oxidation in ground chicken meat at different storage time (carbonyl, nmol/mg of protein; Mean ± SD, n = 6)

Time	FD	SD	P-value
	Raw		
Day 0	0.785±0.140	0.761±0.063	0.712
Day 4	1.429±0.049	0.953±0.078	< 0.0001
Day 7	1.711±0.463	1.168±0.061	0.0343
	Cooked		
Day 0	1.398±0.099	1.384±0.132	0.8424
Day 4	2.712±0.364	2.167±0.108	0.0131
Day 7	4.334±0.304	2.629±0.252	< 0.0001

This may be due to free radical formation, which accelerates during storage time (Estevez, 2011). Sugar based diet (SD) treatment showed a lower increasing rate during storage time of the raw meat samples. Furthermore, total carbonyl values in cooked meat were much higher than those of raw meat and reached up to 4 nmol/mg

protein by the end of storage time (Table 4). Total estimated carbonyl values were reported in the range of 1–3 nmol/mg protein for raw meat and up to 5 nmol/mg protein for cooked meat (Estevez et al., 2005; Sun et al., 2010; Estevez, 2011). This increasing trend of total carbonyl formation was connected to the TBARS or MDA changing the rate of the SD treatment. Certainly, the interaction between both lipid and protein oxidation support this explanation (Xiong, 2000).

These results were in agreement with the findings of Al-Hijazeen et al. (2016), where the TBARS values in both raw and cooked ground chicken meat increased during storage. In addition, the effect of using different levels of essential amino acids with high energy poultry diet has been reported to affect their carcass quality (Moran and Bilgili, 1990; Ellis and Mckeith, 1999; Aletor et al., 2000). In addition, the suitable protein usage in all feeding systems is important economically and nutritionally (Beski et al., 2015). Finally, these results reflect the effect of changes in energy metabolism, nutrient absorption, and amino acid profile due to dietary energy sources (Krajmalnik-Brown et al., 2012).

Meat quality parameters. Water binding ability is considered important in meat quality and its processing characteristics. However, it will affect other eating quality characteristics such as juiciness, texture; flavour and meat marketing benefit (Huff-Lonergan et al., 2005; Cheng and Sun, 2008). In addition to the water binding ability, cooking loss and ultimate pH value of thigh meat samples were measured. Data analysis of the current study showed no significant differences ($P > 0.05$) between both treatments values of cooking loss (Table 5).

Table 5
Effect of dietary treatment on meat quality characteristics (cooking loss, water separation), and pH value of thigh chicken meat (Mean ± SD, n = 6)

Parameter	FD	SD	P-value
[1]Cook L	0.201 ± 0.017	0.166 ± 0.043	0.088
[2]WS	0.257 ± 0.020	0.211 ± 0.024	0.016
[3]pH value	6.240 ± 0.179	5.713 ± 0.262	0.002

Note: [1] – Cook L – cooking loss percentage; [2] – WS – water separation percentage; [3] – pH – ultimate pH value at day 0.

On the other hand, ultimate pH values of meat samples from SD treatment were significantly lower ($P < 0.05$) compared to FD treatment. This effect may be due to glycogen (multi-branched polysaccharide of glucose) stored in the muscle cells, which may affect final pH value in the meat after slaughtering (Den Hertog-Meischke et al., 1997). However, the effect of dietary energy sources on early postmortem muscle metabolism (Glycolytic enzyme) had been reported in several studies (Greenhaff et al., 1988; Li et al., 2017). In addition, treatment samples of FD showed higher significant values of water separation compared to the SD treatment. Despite the lower pH value in the sample of SD, it showed better water binding ability. The reason for this may be due to the effect of fat composition, and the negative effect of lipid oxidation on meat protein. Finally, water holding capacity of raw meat is complicated by many internal and external factors (Huff-Lonergan et al., 2005), for example, physiological, rearing conditions and factors with regard to slaughter and farther processing (Den Hertog-Meischke et al., 1997).

Sensory analysis. Different sensory attributes were evaluated reflecting the relationship between regulator mechanism of meat preservation (pre-postmortem time) and overall meat quality. The evaluation panel of the cooked samples showed no significant differences ($P > 0.05$) between both treatments (FD and SD) using colour and sulfur odour attributes. However, this significant difference could be clearer if the meat samples were evaluated by chemical or instrumental analysis. In addition, FD treatment showed higher significant ($P < 0.05$) scores of the oxidation odour attribute compared to SD (Table 6).

Fatty acids profile and high fat composition of FD samples in muscle tissues may be the reason behind this variation among these attributes (Ellis and Mckeith, 1999; Ahn et al., 2009). In addition, changes in dietary energy source may affect gut microbes, and the mechanism of nutrient absorption (Krajmalnik-Brown et al., 2012). Overall, cooked meat samples from SD treatment were significantly ($P < 0.05$) more acceptable compared to the FD samples (overall acceptability). This could be explained by the differences in fatty acid profile and their amino acid composition (Melton, 1990). These differences usually affect odour, flavour, colour, and other meat quality characteristics, and correlated with lipid and protein oxidation (Min et al., 2008; Ahn et al., 2009).

Table 6
Sensory attributes[b] means of ground chicken thigh meat patties (Mean ± SD)

TRT*	Cooked Colour	Sulfur Odour	Oxidation Odour	Over All Acceptability
		Cooked		
Fat Diet	5.74 ± 1.87	5.28 ± 1.33	7.18 ± 0.74	5.87 ± 1.31
Sugar Diet	7.02 ± 0.97	5.60 ± 0.93	3.99 ± 0.69	7.86 ± 0.77
P-value	0.0688	0.5400	< 0.0001	0.0006
TRT*	Redness Colour	Visual Fat	Oxidation Odour	Over All Acceptability
		Raw		
Fat Diet	5.74 ± 1.45	5.83 ± 0.81	5.73 ± 0.43	4.38 ± 0.93
Sugar Diet	7.13 ± 1.02	2.87 ± 0.48	3.28 ± 0.59	7.75 ± 0.87
P-value	0.0233	< 0.0001	< 0.0001	< 0.0001

Note: * – treatments – fat diet, sugar diet; [b] – sensory attributes – samples of cooked and raw meat were evaluated at day 0 and 3 respectively (n = 10).

Raw meat samples of SD treatment showed higher significant ($P > 0.05$) scores using redness attribute compared to FD treatment. In addition it showed better cooked meat colour scores compared to the FD treatment. Clearly, FD treatment showed higher significant ($P > 0.05$) scores of visual fat attribute. This may be due to the higher fat accumulation in the muscle tissues of broilers that were fed with soy bean oil. Similar to the cooking evaluation, FD treatment samples had significantly ($P < 0.05$) higher scores of oxidation odour using raw meat samples. In addition, SD treatment showed higher significant ($P < 0.05$) scores of the overall acceptability attribute.

Conclusion

The SD treatment showed the lowest significant ($P < 0.05$) lipid and protein oxidation values compared to the other treatment. In addition, FD treatment showed higher significant water separation of raw thigh meat samples. Results of the sensory evaluation were in agreement with the previous chemical analysis data. It can be concluded that SD treatment could be a good replacement to the FD in term of meat storage stability if used in a suitable level. However, more research studies are needed to ascertain all meat quality characteristics. Finally, this regulatory bio-system approach should have a promising future in poultry production and meat preservation. In addition, it will enhance food safety, decrease carcinogenic and toxicological effects of free radicals, and improve human health.

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