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# The Effect of Dietary Concentrate Level and Poultry Offal Meal Supplementation on the Cholesterol Content of Najdi Lambs Muscle

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**Abstract.** Total lipid and cholesterol content in longissimus muscle and carcass soft tissue from Najdi ram lambs as affected by dietary concentrate level and poultry offal meal supplementation (POM) were studied. Sixty lambs, weighing 23.5 kg were assigned to a 2 × 3 factorial arrangement consisting of two dietary concentrate levels (high; 70% concentrate or low; 25% concentrate) and three POM supplementation (0, 5 and 10%); POM replaced an equal amount of soybean meal in the diet. All six diets were isonitrogenous (14.9% CP) and diets within each dietary concentrate level were isocaloric (high; 11.7 and low; 9.0 MJ ME/kg DM). Lambs were individually given *ad libitum* access to feed for 120 days before slaughter. The results showed that, no significant differences were detected in total lipid content and cholesterol content of longissimus muscle or carcass soft tissue between various levels of POM supplementation. High-concentrate fed lambs had more ($P < 0.01$) total lipid content in their longissimus muscle and carcass soft tissue than low-concentrate fed lambs. Dietary concentrate level had no effect on longissimus muscle cholesterol concentration, whereas, carcass soft tissue from high-concentrate fed lambs had less ($P < 0.01$) cholesterol concentration than those from low-concentrate group. The overall least-squares mean for longissimus muscle was 66.3 mg of cholesterol/100 g of tissue. Generally, cholesterol concentration were 21.4 and 35.3% higher in carcass soft tissue from high- and low-concentrate fed lambs compared to longissimus muscle, respectively.

## Introduction

There is a growing concern that animal fat and cholesterol consumption may be associated with a high incidence of coronary heart disease in humans. Meat has been perceived as high in cholesterol concentration and thus, as contributing significantly to dietary cholesterol intake. The reported mean values for cholesterol range from

62.4mg/100g to 77.2mg/100g of longissimus muscle (wet-weight basis) from lambs of various genetic origin and wide variability of dietary regimen [1,2]. Although, there are conflicting reports regarding the effect of animal diets on muscle cholesterol content, several reported literature supported the concept of constancy of tissue concentrations of cholesterol as a result of the presence of cholesterol as an integral component of adipocyte cell membranes [3,4]. In that connection, Holmes *et al.* [5] reported no differences in muscle cholesterol content when the roughage level of the diets were increased from 28 to 74%. Also, Lough *et al.* [1] and Solomon *et al.* [6] found no influence of animal diet on cholesterol content of the longissimus muscle for lambs fed wide variety of lipids in diets. Previously, Al-Suwaid [7] reported the effects of feeding 5 and 10% poultry offal meal (POM; 32% ether extract) supplementation to the diets on performance and carcass characteristics of growing Najdi ram lambs. This paper, however, reports the effects of POM supplementation to high- and low-concentrate diets on total lipid content and cholesterol content of carcass tissues of those same Najdi lambs.

## Materials and Methods

Sixty Najdi ram lambs were randomly assigned in a 2 × 3 factorial arrangement of two dietary concentrate levels (high, 70:30; low, 25:75 concentrate: roughage ratio) and three levels of POM supplementation (0, 5 and 10%). Chemical analysis and *in vivo* studies of POM showed that it contained 54% CP of a low degradation rate in the rumen and 32% ether extract [7,8]. Accordingly, all experimental diets were prepared to be isonitrogenous (14.9% CP) and diets within each dietary concentrate level were isocaloric; the high- and low-concentrate diets contained 11.7 and 9.0 MJ of ME/kg DM (Table 1), respectively. It should be mentioned that POM was supplemented to replace an equal amount of soybean meal in the diet. Management of the lambs were previously described [7]. The lambs were started on trial at approximately 3.5 months of age (average 23.5 kg body weight) and were individually fed *ad libitum* and slaughtered after a 120-days feeding period.

Loin sections were removed from each carcass at 48 h postmortem. The *M. longissimus* dorsi muscle from the right side posterior to the 13th rib (10 cm in length) was excised, trimmed of all external visible fat and connective tissue, finely minced and mixed thoroughly and sampled. The left side of each carcass was dissected into carcass soft tissue (boneless carcass) and bone. Thereafter, all components of carcass soft tissue; namely, lean, subcutaneous fat, intermuscular fat and intramuscular fat were pooled, finely minced and mixed thoroughly three times and sampled. Samples

**Table 1. Ingredients and composition of experimental diets[a]**

| Ingredients, % | High concentrate | | | Low concentrate | | |
|---|---|---|---|---|---|---|
| | Levels of poultry offal meal | | | | | |
| | 0 | 5 | 10 | 0 | 5 | 10 |
| Poultry offal meal | – | 5.0 | 10.0 | – | 5.0 | 10.0 |
| Soybean meal | 10.0 | 5.0 | – | 10.0 | 5.0 | – |
| Barley | 29.3 | 34.0 | 38.0 | 4.5 | 9.2 | 13.0 |
| Corn starch | 8.7 | 4.0 | – | 8.5 | 3.8 | – |
| Yellow corn | 20.5 | 20.5 | 20.5 | – | – | – |
| Wheat straw | 6.1 | 10.1 | 13.6 | 28.4 | 32.4 | 35.4 |
| Alfalfa hay | 23.9 | 19.9 | 16.4 | 48.1 | 44.1 | 41.1 |
| Salt and minerals[b] | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Sodium bicarbonate | 1.0 | 1.0 | 1.0 | – | – | – |
| Crude protein, %[c] | 15.5 | 15.1 | 16.7 | 15.5 | 16.4 | 16.4 |
| TDN[cd] | 69.7 | 68.5 | 68.2 | 55.2 | 53.2 | 52.0 |
| ME/kg DM, MJ[e] | 11.7 | 11.7 | 11.7 | 9.0 | 9.0 | 9.0 |

[a] Dry matter basis.
[b] Contained 10% Mn, 10% Fe, 10% Zn, 1% Cu, 0.3% I and 0.1% Co.
[c] Laboratory determined.
[d] Total digestible nutrients.
[e] Calculated.

consisted of approximately 30g of tissue. All samples were stored frozen at −20°C pending lipid and cholesterol analysis.

Upon chemical analysis, each longissimus muscle or carcass soft tissue sample was homogenized and extracted three times according to Folch procedure [9] using chloroform-methanol (2:1, v/v) as the extraction medium. A 10 ml-aliquot (three replications/sample) of the lipid extract was freed of solvent and its lipid content was determined. Thereafter, aliquots of the lipid extract were transferred to screw-cap test tubes for subsequent cholesterol analyses.

Cholesterol content of each sample was determined in triplicate. A 6 ml-aliquot (equivalent to 0.3g tissue) of the lipid extract was freed of solvent using a stream of

nitrogen while the tube containing the extract was warmed in a 55-60°C water bath. The lipid residue was saponified by heating with 5 ml of 15% KOH in a water bath shaker at 88°C for 15 min. A 5 ml of distilled water was added to the mixture which was eventually cooled to room temperature. The unsaponifiable materials were extracted twice with 10 ml of hexane for each extraction. A 4 ml-aliquot of the hexane extract was freed of solvent, as described above, and assayed for cholesterol concentration according to the colorimetric procedure discribed by Eichhorn *et al.* [10]. Data were analyzed by the GLM procedure of SAS [11] to determine the significance of variation among experimental diets.

## Results and Discussion

Total lipid content and cholesterol content of longissimus muscle and carcass soft tissue of the growing Najdi ram lambs fed the experimental diets are presented in (Table 2). Total lipid content (g/100 g of tissue) in longissimus muscle and carcass soft tissue did not vary as POM in the diet increased, and were higher ($P < 0.01$) in carcasses from high-concentrate fed lambs than from low-concentrate fed groups. Cholesterol content in longissimus muscle (mg/100 g of tissue) was not significantly influenced by the dietary concentrate level or by the level of POM supplementation in the diets. Longissimus muscle contained an average of 66.3 mg cholesterol/100 g of muscle (wet-weight basis). These results are slightly higher than those of Lough *et al.* [1], lower than those of Solomon *et al.* [2] and comparable to those reported by Solomon *et al.* [12,6]. The lack of significant differences in longissimus muscle cholesterol content between high- and low-concentrate fed lambs in our experiment agreed well with the findings of other workers. Eichhorn *et al.* [10] reported no effect due to length of grain feeding, and Taylor and Smith [13] reported no differences in muscle cholesterol content between the pasture-fed and the grain-fed Hereford steers. Also, Holmes *et al.* [5] did not observe a reduction in cholesterol content of lean tissue when the roughage level of the diets were increased from 28 to 54 to 74%, suggesting that tissue cholesterol level in meat animals does not respond to animal diet modifications. In that connection, feeding palm oil-supplemented diet increased serum cholesterol significantly in lambs but did not alter muscle cholesterol levels, concluding that cholesterol uptake by muscle is receptor-mediated and not concentration-dependent [6]. It might be expected that as the intramuscular fat content increases in longissimus muscle (Table 2) there would be an increase in muscle cholesterol content; a large proportion of the cholesterol in muscle is present in lipid cell membrane [3]. Nevertheless, in the data presented here, the ragne in the percentage of intramuscular fat was 2.9-4.9%, which could well have been too small a range to elicit a significant effect. Similar findings were reported by Rhee *et al.* [3], Wheeler

*et al.* [14] and Taylor and Smith [13] who reported that muscle cholesterol content did not vary over a range of intramuscular fat percentages of 3.63- 12.08%, 1.03-3.64% and 1.8-2.7%, respectively.

The cholesterol content in carcass soft tissue did not vary as POM in the diet increased, and was higher ($P < 0.01$) in carcasses from low-concentrate fed lambs than from high-concentrate group. Similar results concluded that higher energy diet resulted in lower cholesterol concentration in fat tissue than did a maintenance diet in cows [10]. Therefore, the increased deposition of lipid in the adipose tissue of lambs on high-concentrate diets (37.9 vs 27.7%) probably diluted the concentration of cholesterol in the tissues. Related results found that adipocyte cell numbers in beef remained constant with increased time on feed but enlarged significantly in size resulted in a dilution of the concentration of the structural components of the cell [4].

Average cholesterol contents of the carcass soft tissue from low- and high-concentrate fed lambs were 23.1 and 14.9 mg/100 g of tissue higher than the cholesterol content in longissimus muscle, respectively. Carcass soft tissue included all carcass lean, subcutaneous, intermuscular and intramuscular fats. Farkas *et al.* [15] reported that adipose tissue is a cholesterol storage site and accumulates amounts greater than

**Table 2. Effects of dietary concentrate level (CL) and poultry offal meal (POM) supplementation on total lipid content and cholesterol content in Longissimus muscle (LM) and carcass soft tissue (ST) of Najdi ram lambs**

| Item | CL: | High concentrate | | | Low concentrate | | | SEM | Significance | |
|---|---|---|---|---|---|---|---|---|---|---|
| | POM: | 0 | 5 | 10 | 0 | 5 | 10 | | CL | POM |
| Total lipid (g/100 g tissue): | | | | | | | | | | |
| LM | | $4.8^{b}$ | $4.7^{b}$ | $4.9^{d}$ | $3.3^{a}$ | $2.9^{a}$ | $2.9^{a}$ | 0.21 | ** | NS |
| ST | | $37.1^{b}$ | $38.4^{b}$ | $38.2^{b}$ | $27.0^{a}$ | $28.1^{a}$ | $27.9^{a}$ | 0.51 | ** | NS |
| Cholesterol (mg/100 g tissue): | | | | | | | | | | |
| LM | | 66.9 | 66.8 | 65.2 | 68.8 | 66.0 | 65.3 | 1.12 | NS | NS |
| ST | | $81.4^{a}$ | $79.6^{a}$ | $80.5^{a}$ | $88.3^{b}$ | $89.9^{b}$ | $91.1^{b}$ | 1.65 | ** | NS |
| Cholesterol (g/100 g lipid): | | | | | | | | | | |
| LM | | $1.39^{a}$ | $1.38^{a}$ | $1.33^{a}$ | $2.08^{b}$ | $2.28^{b}$ | $2.25^{b}$ | 1.67 | ** | NS |
| ST | | $0.22^{a}$ | $0.21^{a}$ | $0.21^{a}$ | $0.33^{b}$ | $0.32^{b}$ | $0.33^{b}$ | 0.05 | ** | NS |

$^{a,b}$ Values in the same row bearing different superscripts are different ($P < 0.01$).
** ($P < 0.01$); NS = ($P < 0.05$).

those needed for cellular functions, which may explain its higher content compared to longissimus muscle tissue. In general agreement with these findings, Rhee *et al.* [3] reported a concentration of 62 mg/100 g of muscle dissected from rib steaks compared to 114 mg/100 g of subcutaneous fat or 108 mg/100 g of intermuscular fat. Wheeler *et al.* [14] reported 35.6 mg/100 g higher in subcutaneous fat than in longissimus muscle. Also, Lough *et al.* [1] found a concentration of 62.4 mg/100 g of longissimus muscle vs. 78 mg/100 g of subcutaneous fat isolated from lambs.

When cholesterol content was calculated on a lipid content basis (g/100 g of lipid), longissimus muscle and carcass soft tissue from low-concentrate fed lambs had significantly higher ($P < 0.01$) cholesterol content than those tissues from high-concentrate fed lambs. The correlation coefficients (Table 3) between lipid content in longissimus muscle and cholesterol content (g/100 g of lipid) in the muscle, and between lipid content in carcass soft tissue and its cholesterol content (g/100 g of lipid) were $-0.53$ and $-0.61$ ($P < 0.01$), respectively. These results together with the non-significant correlations found between lipid content and cholesterol content expressed on a wet-tissue basis for both longissimus muscle and carcass soft tissue confirming the previous results [3,4] that a large proportion of cholesterol in meat is associated with lipid cell membrane and intracellular structures.

**Table 3. Correlation coefficients[a] between cholesterol content of longissimus muscle (LM) or carcass soft tissue (ST) and their respective total lipid content**

| | Cholesterol (mg/100 g tissue) | Ciholesterol (g/100 g lipid) |
|---|---|---|
| Lipid in LM | 0.139 | $-0.534^{**}$ |
| Lipid in ST | $-0.244$ | $-0.608^{**}$ |

[a] $n = 60$

** $P < 0.01$

On the basis of results from the present study, it is obvious that cholesterol concentration in the tissues of growing lambs is generally not influenced by type of dietary protein and/or the amount of dietary fat supplemented to the diet. Furthermore, meat from high-concentrate fed lambs should not be criticized for contributing to ingested cholesterol any more than that meat from lambs fed on high-roughage based diets. The general recommendation is to limit intake to 100 mg cholesterol/1000 kcal, not to exceed 300 mg/day [16]. Therefore, the cholesterol content of lamb meat, on the basis of 150/g serving of longissimus muscle or 120/g carcass soft tissue, is consistent with the formerly mentioned recommendation [16] and compares favourably with poultry and fish.

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# تأثير نسبة العلف المركز ومسحوق أحشاء الدواجن في العليقة على تركيز الكولسترول في عضلات الحملان النجدي

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*(ورد البحث في ١٤١٥/٩/١٥هـ؛ وقُبل للنشر في ١٤١٥/١٢/٢٩هـ)*

**ملخص البحث**. استخدم في هذه التجربة ٦٠ حملاً نجديًا متوسط أوزانها عند بدء التجربة ٢٣,٥ كجم، وقد وزعت الحملان عشوائيًا وبالتساوي على مستويين من طاقة الغذاء (عالى ٧٠٪ مركزات، منخفض: ٢٥٪ مركزات) وبداخل كل مستوى من الطاقة أضيف مسحوق أحشاء الدواجن إلى الغذاء ليحل محل نسبة مساوية من فول الصويا بثلاثة مستويات مختلفة (صفر، ٥، ١٠٪)، وغذيت الحملان على هذه العلائق بصورة حرة وفردية لمدة ١٢٠ يومًا قبل الذبح. احتوت جميع العلائق على نسبة ثابتة من البروتين الخام (١٤,٩٪) بينما احتوى الغذاء عالي الطاقة على ١١,٧ ميجاجول والغذاء منخفض الطاقة على ٩ ميجاجول طاقة ممثلة لكل كجم غذاء جاف. أظهرت النتائج أن إضافة مسحوق أحشاء الدواجن إلى غذاء الأغنام ليس له تأثير معنوي ($P > 0.01$) على تغير نسبة الدهون الكلية أو الكولسترول في العضلة العينية والأنسجة الطرية للذبائح، بينما تغذية الحملان على علائق تجريبية عالية الطاقة أدت إلى ارتفاع ملحوظ ($P < 0.01$) في نسبة الدهون الكلية بالمقارنة مع أنسجة الذبائح المنتجة من الحملان المغذاة على علائق منخفضة الطاقة. لم يتأثر تركيز الكولسترول في العضلة العينية باختلا ف مستوى طاقة الغذاء المقدم للحملان، وهذا على عكس تركيز الكولسترول في الأنسجة الطرية للذبائح حيث كان أقل ($P > 0.01$) في أنسجة الحملان المغذاة على طاقة عالية بالمقارنة مع تلك المغذاة على طاقة منخفضة. وقد وجد أن متوسط تركيز الكولسترول ٦٦,٣ مجم/١٠٠جم من العضلة العينية. وبصورة عامة فإن نسبة الكولسترول في الأنسجة الطرية للذبيحة المنتجة من حملان مغذاة على علائق عالية الطاقة أو منخفضة الطاقة كانت أعلى من تلك التركيزات الموجودة في العضلة العينية بمعدل ٢١,٤٪ و ٣,٣٥٪ على التوالي.