Effects of underfeeding and refeeding on offals weight in the Barbary ewes

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Received 20 May 1999; accepted 24 February 2000

Abstract

The influence of long-term (161 days) underfeeding and refeeding (154 days) on the weight of offal components, and digestive content, was studied in 26 adult Barbary ewes. Effects on the protein and mineral content of offals were also measured. Animals were split in three groups: one was fed hay at maintenance level (M), another also received vetch–oat hay to cover 0.2 of maintenance energy requirements (L), and the third one was fed at 0.2 of maintenance requirements during 161 days, then refed at 1.3 times of energy requirements with a diet of hay and barley grain (LH) during 154 days. Underfed animals body weight (BW) at slaughter was 31 kg. Animals of groups M and LH were slaughtered at similar BW (50 kg). Underfeeding reduced empty BW by 38% and the weight of most metabolically active organs: skin (40%), blood (31%), rumen (34%) and liver (19%), but not others (small intestine). Total offals weight was reduced by 27%. Overfeeding of previously underfed animals (LH) induced a significant increase in liver weight in comparison to M group (18%), owing to a higher nutrient supply. The amount of protein in offals and their fat-free weight were decreased by underfeeding, whereas the amount of minerals was significantly modified only in components rich in bone. These results showed that splanchnic organ mass decreases with underfeeding which leads to energy requirements decrease and contributes towards resistance of Barbary ewes to harsh food conditions.

Keywords: Ewe; Underfeeding; Refeeding; Offal weight; Digestive contents

1. Introduction

In ruminants, climatic uncertainty, as well as economic or physiological causes, often lead to sequences of underfeeding and refeeding (Chilliard et al., 1998). Variations in food intake result in modifications of weight of digestive tract and liver, which occur within a few weeks (Koong et al., 1982; Johnson et al., 1990; Ortigues and Doreau, 1995). The determination of the weight of these organs is of interest due to their large contribution (>50%) to maintenance energy expenditure (Baldwin et al., 1980; Ortigues, 1991). On the other hand, differences in energy expenditure related to variations in feeding level are also due to weight variation of other offal components, such as skin (Harris et al., 1994). However, the effects of long-term underfeeding are not well known. The effects of sequential underfeeding, then refeeding, on weight and composition of offal have been studied in growing animals in the case of compensatory gain (Drouillard et al., 1991; Kabbali et al., 1992; Ortigues and Doreau, 1995), but are not well known in adult ruminants.
The Barbary breed sheep exhibit a very high potential of adaptation to seasonal variations in live weight (Khaldi, 1989) and body condition score (Atti and Abdennebi, 1995; Atti and Bocquier, 1999). The objective of this work was to study the effects of a long term and very marked undernutrition followed by refeeding on the weights at slaughter of the different components of offals and their chemical composition in adult Barbary ewes.

2. Materials and methods

2.1. Animals and feeding

Twenty six adult, non-pregnant, non-lactating ewes of Barbary breed, were separated in three homogeneous groups which were matched as closely as possible by live weight (mean 49 kg), age (mean 4.4 years) and body condition score (mean 3.9 on a 0–5 scale). Ewes of the first group (group M, 9 ewes) were fed 0.88 kg DM of a vetch–oat hay per head daily throughout the experiment (315 days) and were then slaughtered. In the second group (group L, 9 ewes), ewes received only 0.18 kg DM of the same hay per day for 161 days prior to slaughter. Ewes of the third group (group LH, 8 ewes) were fed like those of the group L for 161 days and then refed. They received 1.1 kg DM of the same hay per day for 70 days, then 0.88 kg DM of hay and 0.45 kg barley grain for 84 days; ewes were slaughtered after 315 days on test. The net energy value was 1.22 and 1.84 Mcal/kg DM and the CP concentration was 77 and 122 g/kg DM for hay and barley grain, respectively. Energy supply of the diets corresponded to 100 (group M), 20 (group L), 20, then 130% (group LH) of maintenance requirements calculated from initial live weight according to INRA (1989). The length of refeeding period was determined so that the average body weight at slaughter was the same for groups M and LH. Mean body weights at slaughter were 50, 31 and 50 kg for groups M, L and LH, respectively.

2.2. Tissue sampling and analysis

After slaughter, blood was collected and weighed. After removing internal (mesenteric plus omental) fat, weights of the different components of offals were determined: skin, head, feet, thoracic organs (heart, lungs+trachea), viscera (digestive tract, spleen, liver, kidney). Digestive tract was divided in five parts: reticulo- rumen+omasum, abomasum, small intestine, caecum and colon. All these fractions were weighed full, then empty, after hand rinsing, in order to determine digestive contents. Empty body weight (EBW) was calculated as the difference between live weight just before slaughter and digestive contents. Dry matter was determined on three samples of digestive contents for each compartment. For each animal, the organs were divided in two parts. The first one was composed of head, feet and skin, the second one included thoracic and abdominal organs. These two fractions were kept frozen at −20°C until grinding in liquid nitrogen. Three minced samples were used for dry matter (DM) determination, then ground again before chemical analysis.

DM was determined by drying at 80°C until constant weight. Mineral content was determined by ashing at 600°C for 8 h. Nitrogen was determined by the Kjeldahl method (CP=N×6.25). Lipids were estimated as the difference between DM and the sum of protein and ash. Lipid-free weight of internal organs was calculated as the sum of protein and mineral masses. This value allowed a more accurate determination of weight variations because in some organs, such as intestines, mesenteric fat is not easy to completely remove from the intestinal wall.

2.3. Statistical analysis

Statistical analysis of the weight and the proportion of organs in EBW was performed by analysis of variance with a model fitted as follows:

\[ y_{ij} = \mu + \text{group}_i + a\text{EBW} + e_{ij} \]

here, \( y_{ij} \) is the response of the \( j \)th ewe in the \( i \)th group (i.e. L, M or LH) EBW: covariable.

A previous analysis without covariable was performed and gave similar results. Statistical analysis of data concerning the weight of digesta was performed by one-way (group L, M or LH) analysis of variance. All analyses were performed using the GLM procedure of Statistical Analysis System (1988). Differences between groups were evidenced by the Duncan t-test. Significance was declared at \( p<0.05 \).
3. Results

3.1. Weight of offal components

Means for EBW and total offal weight were similar for groups M and LH and higher than those of group L (Table 1). EBW and offal weight were lower by 38 and 27% for group L than for group M, respectively. Weight of some components of low metabolic activity in adult animals (feet, lungs+trachea) and of abomasum, small intestine and caecum were not affected (p>0.05) by feeding treatment. Weight of colon was higher for group LH than for group L; weight of group M being intermediate and non-significantly different from that of the other two groups. Liver weight was higher for group LH than for group M, and higher for group M than for group L (p<0.01). Weights of other organs were similar for groups M and LH and higher than those for group L: head (p<0.05), blood, kidney and spleen (p<0.01), skin, heart, reticulo-rumen+omasum and total digestive tract (p<0.001). Weights of skin, blood, reticulo-rumen+omasum and liver decreased by 40, 31, 34 and 13%, respectively, when animals were underfed (L vs. M), and increased by 70, 47, 57 and 45%, respectively, when they were refed (LH vs. L). With both underfeeding and refeeding, skin, blood, reticulo-rumen and liver explained 60, 28, 18 and 6% of changes in offal weight, respectively.

When expressed as a percentage of EBW, skin (8%), blood (5.2%) and reticulo-rumen+omasum (3%) were not affected (p>0.05) by feeding treatment. On the other hand, liver and total digestive tract proportions depended on the feeding regimen. For groups L, M and LH, respectively, it was 1.6, 1.2 and 1.4% of EBW for liver (p<0.01), and 7.8, 6.1 and 6.4% of EBW for digestive tract (p<0.001).

The fresh weight of empty digestive tract (DT) was significantly (p<0.001) related to DM intake (I) according to the equation:

\[ DT(g) = 1911 + 0.675 I(g); \quad r = 0.82; \quad n = 26; \quad RSD = 228 g \]

3.2. Ash and protein content

Ash content of skin and organs rich in bone (feet and head) was the same for animals of groups M and LH.

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Table 1
Means for empty body weight (kg), total offal weight and fresh weight (without digesta) of organs (g) for different groups

<table>
<thead>
<tr>
<th>Group</th>
<th>Empty body weight</th>
<th>Total offal weight</th>
<th>Head</th>
<th>Feet</th>
<th>Skin</th>
<th>Spleen</th>
<th>Heart+pericardic fat</th>
<th>Liver</th>
<th>Lungs+trachea</th>
<th>Kidneys</th>
<th>Reticulo-rumen+omasum</th>
<th>Abomasum</th>
<th>Small intestine</th>
<th>Caecum</th>
<th>Colon</th>
<th>Whole digestive tract</th>
<th>Blood</th>
</tr>
</thead>
<tbody>
<tr>
<td>L</td>
<td>25.79 a</td>
<td>8313 a</td>
<td>2059 a</td>
<td>863</td>
<td>2025 a</td>
<td>88 a</td>
<td>211 a</td>
<td>422 a</td>
<td>566</td>
<td>73 a</td>
<td>797 a</td>
<td>240</td>
<td>371</td>
<td>191</td>
<td>407 a</td>
<td>2006 a</td>
<td>1441 a</td>
</tr>
<tr>
<td>M</td>
<td>41.80 b</td>
<td>10844 b</td>
<td>2311 b</td>
<td>924</td>
<td>3377 b</td>
<td>136 b</td>
<td>291 b</td>
<td>519 b</td>
<td>653</td>
<td>102 b</td>
<td>1202 b</td>
<td>222</td>
<td>371</td>
<td>222</td>
<td>514 ab</td>
<td>2532 b</td>
<td>2080 b</td>
</tr>
<tr>
<td>LH</td>
<td>43.34 b</td>
<td>11204 b</td>
<td>2359 b</td>
<td>906</td>
<td>3444 b</td>
<td>135 b</td>
<td>294 b</td>
<td>613 c</td>
<td>602</td>
<td>97 b</td>
<td>1255 b</td>
<td>229</td>
<td>478</td>
<td>224</td>
<td>568 b</td>
<td>2753 b</td>
<td>2112 b</td>
</tr>
</tbody>
</table>

SEM: 1.24; 322; 87; 33; 238; 10; 14; 18; 33; 4; 52; 18; 36; 29; 14; 76; 94

Effect: ***; ***; *; NS; ***; **; NS

* Animals underfed.
b Animals fed at maintenance.
c Animals underfed, then refed.
d Means in the same row with different letters differ (p<0.05).
e Non-significant (p>0.05).
* p<0.05; ** p<0.01; *** p<0.001.
whereas it was lower \((p < 0.05)\) for animals of group L (Table 2). Ash content of internal organs did not differ among groups. Protein content of whole offals and lipid-free weight of these organs were the same in groups M and LH, but were lower than those of group L.

### 3.3. Digestive tract contents

The fresh weight of digestive tract contents was similar for groups M and LH (7500 g; SEM 265 g) and higher than that of group L (4.6 kg), but represented a mean of 15% of live weight in the three groups (Table 3). Similarly, weight of dry digestive contents in each compartment was the same for groups M and LH, and lower for group L. Dry digestive tract contents of all compartments except colon were significantly correlated with dry total digestive contents, the highest correlation coefficients \((p<0.01)\) being obtained for reticulo-rumen-omasum \((r=0.99)\), which represents the major part of contents, and for

### Table 2
Mean protein, mineral and lipid-free weight of offals (g) for different groups

<table>
<thead>
<tr>
<th></th>
<th>Group L(^a, d)</th>
<th>Group M(^b, d)</th>
<th>Group LH(^c, d)</th>
<th>SEM</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal organs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Proteins</td>
<td>530 a</td>
<td>1075 b</td>
<td>986 b</td>
<td>56</td>
<td>***</td>
</tr>
<tr>
<td>Ash</td>
<td>29</td>
<td>24</td>
<td>26</td>
<td>3</td>
<td>NS(^e)</td>
</tr>
<tr>
<td>Lipid-free weight</td>
<td>529 a</td>
<td>1099 b</td>
<td>1012 b</td>
<td>55</td>
<td>***</td>
</tr>
<tr>
<td>Skin, head, feet</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Proteins</td>
<td>884 a</td>
<td>1111 b</td>
<td>1122 b</td>
<td>58</td>
<td>(\ast)</td>
</tr>
<tr>
<td>Ash</td>
<td>543 a</td>
<td>879 b</td>
<td>814 b</td>
<td>68</td>
<td>**</td>
</tr>
<tr>
<td>Lipid-free weight</td>
<td>1427 a</td>
<td>1990 b</td>
<td>1936 b</td>
<td>103</td>
<td>**</td>
</tr>
</tbody>
</table>

\(^a\) Animals underfed.

\(^b\) Animals fed at maintenance.

\(^c\) Animals underfed then refed.

\(^d\) Means on the same row with different letters differ \((p<0.05)\).

\(^e\) Non-significant \((p>0.05)\).

\(\ast\) \(p<0.05\); \(\ast\) \(p<0.01\); \(\ast\) \(p<0.001\),

### Table 3
Average feed intake and mean weight of digesta in the different parts of the digestive tract for different groups

<table>
<thead>
<tr>
<th></th>
<th>Group L(^a, d)</th>
<th>Group M(^b, d)</th>
<th>Group LH(^c, d)</th>
<th>SEM</th>
<th>Effect (^e)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed intake (g DM/day)</td>
<td>176</td>
<td>850</td>
<td>1298</td>
<td></td>
<td>–</td>
</tr>
<tr>
<td>Reticulo-rumen-omasum</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fresh weight (g)</td>
<td>3260 a</td>
<td>5672 b</td>
<td>5727 b</td>
<td>174</td>
<td>***</td>
</tr>
<tr>
<td>DM (g)</td>
<td>344 a</td>
<td>1060 b</td>
<td>979 b</td>
<td>101</td>
<td>***</td>
</tr>
<tr>
<td>Total digestive contents (%)</td>
<td>68.6</td>
<td>76.7</td>
<td>73.7</td>
<td>15.3</td>
<td>NS(^f)</td>
</tr>
<tr>
<td>Abomasum (g DM)</td>
<td>8 a</td>
<td>34 b</td>
<td>41 b</td>
<td>4</td>
<td>***</td>
</tr>
<tr>
<td>Small intestine (g DM)</td>
<td>30 a</td>
<td>79 b</td>
<td>82 b</td>
<td>8</td>
<td>***</td>
</tr>
<tr>
<td>Caecum (g DM)</td>
<td>76 a</td>
<td>158 b</td>
<td>166 b</td>
<td>9</td>
<td>***</td>
</tr>
<tr>
<td>Colon (g DM)</td>
<td>38</td>
<td>46</td>
<td>55</td>
<td>13</td>
<td>NS</td>
</tr>
<tr>
<td>Total digestive tract</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fresh weight (g)</td>
<td>4638 a</td>
<td>7460 b</td>
<td>7471 b</td>
<td>265</td>
<td>***</td>
</tr>
<tr>
<td>DM (g)</td>
<td>494 a</td>
<td>1377 b</td>
<td>1323 b</td>
<td>115</td>
<td>***</td>
</tr>
</tbody>
</table>

\(^a\) Animals underfed.

\(^b\) Animals fed at maintenance.

\(^c\) Animals underfed then refed.

\(^d\) Means on the same row with different letters differ \((p<0.05)\).

\(^e\) *** \(p<0.001\); \(\ast\) \(p<0.01\).

\(^f\) Non-significant \((p>0.05)\).
the caecum \((r=0.94)\). A strong linear relationship was observed for percentage of DM between reticulo-rumen+omasum and total digestive tract.

4. Discussion

The weight of offal components rich in bone and/or with a low metabolic activity (head, feet, lungs) varied little with undernutrition (M vs. L). However, those organs are early maturing parts, hence, and in accordance with Kamalzadeh et al. (1998), those parts are less affected than the late maturing organs by feed restriction. In our trial, the loss of ash accounted to a large extent for the decrease in the weight of offal components rich in bones. These results suggest that bones can be mobilised in underfed adults, contrary to the observation in restricted growing lambs (Aziz et al., 1993).

The weight of some organs or tissues was higher for group M than for group L. This may be the case when their activity directly depends on blood flow, which is related to intake. This applies for skin (Harris et al., 1994), heart, spleen, kidney and blood (Gill et al., 1989). In the same way, the weight of digestive tract and liver, for which energy expenditure increases with intake (Lindsay, 1993; Reynolds, 1995), is higher for group M than for group L. On the contrary, weights of abomasum and small intestine did not vary between these two groups, and the decrease in weight of splanchnic organs when animals are underfed arises only from reticulo-rumen+omasum and liver. These results confirm those of Fluharty and McClure (1997) on growing lambs restricted to 85% of their requirements, and those of Nozière et al. (1999) on adult ewes restricted to 40% of their requirements. It may be concluded that, below a given body weight, abomasum and small intestine do not respond to variations in intake. Our results confirm the positive relationship between the weights of reticulo-rumen, large intestine and liver on the one hand, and intake on the other, clearly established in growing animals (Murray et al., 1977; Drouillard et al., 1991; Kabbali et al., 1992) and in adults (Robelin et al., 1990; Nozière et al., 1999). The loss of protein contributes, to a large extent (33%), to the loss of DM of internal organs, as also observed by Nozière et al. (1999) in splanchnic organs of underfed ewes. This decrease in protein mass, associated with the high metabolic activity of splanchnic organs, is probably largely involved in the variations of energy maintenance expenditure when animals are underfed (Ortigues, 1991).

In this trial, offals significantly contributed to protein and mineral mobilisation due to a marked undernutrition characterised by energy supply lower than maintenance requirements. The response differs from that of relative undernutrition in early lactating cows fed at a higher level than maintenance, but lower than their requirements; in this case, animals mobilise their body lipids, but no protein mobilisation of digestive organs occurs (Doreau et al., 1985). Indeed, mobilisation of body protein does not occur to any appreciable extent if the feed restriction is not severe and there is body lipid available to meet metabolic demands.

Despite a very marked undernutrition, the weight loss of splanchnic organs was less than that in growing animals (Johnson et al., 1990; Kabbali et al., 1992). It is likely that the weight of splanchnic tissues rapidly decreases as soon as undernutrition begins (Rompala et al., 1988; Richmond et al., 1988), thereafter, it is stabilised at a level which depends on digesta mass and nutrient supply. On the contrary, body reserves, apart from offals, decrease more slowly but for a longer time. It has already been shown that changes in weight of digestive tract and liver, which depends on slaughter weight, are not proportional to changes in body weight (Winter et al., 1976; Koong et al., 1982; Taylor and Murray, 1991).

Except for liver, the weight of offal components was not different between groups M and LH, despite the difference in previous nutrition. This suggests that the weight of most offal components depends more on weight at slaughter, which was the same in these two groups, than on level of intake or on the ratio between supply and requirements, and that the type of diet is of minor importance. There was no carry-over effect of the previous extended undernutrition, whereas in growing animals a carry-over effect of previous nutrition is observed, although to a limited extent (Kabbali et al., 1992; Ortigues and Doreau, 1995). This may be due to the fact that weight variations of digestive tract are very rapid. The amount of digesta, which is similar for groups M and LH, may mediate the effect of feeding level on the weight of digestive tract (Rompala
et al., 1988; Ortigues and Doreau, 1995). In comparison, nutrients produced by fermentation of the concentrate are probably important factors in changes in liver weight with feeding level (Ortigues and Doreau, 1995), explaining the higher weight of liver in refed ewes than in ewes fed at maintenance. Similar results, concerning changes in liver weight with feeding level, have been obtained by other authors in growing (Sun et al., 1994; Sainz and Bentley, 1997), and adult, animals (Nozière et al., 1999).

The proportion of offal in EBW was significantly higher for group L than for the other two groups. As a consequence, the dressing percentage yield is lower when animals are underfed for a long period than when animals are fed according to their requirements. The increase in the proportion of offal in underfed animals is mainly due to body fat mobilisation as shown by Aziz et al. (1993) in growing lambs. The extent of the increase in the proportion of splanchnic organs in EBW, from 1.2 to 1.6% of EBW for liver and from 6.1 to 7.8% of EBW for digestive tract between groups M and L, respectively, is lower than that reported by Keenan et al. (1969) in adult ewes during loss of live weight (1.1 to 2.2% of EBW for liver). The very long period of undernutrition in the present trial probably reduced variations in weight of splanchnic tissues in proportion to EBW, because when animals are underfed for a short period splanchnic tissues may vary more rapidly than other tissues.

As often mentioned (Campling and Freer, 1966; Agabriel and Petit, 1987; Rémond et al., 1995), the mass of digestive contents varied in the same way as feed intake, for a constant diet composition. Moreover, the lower DM percentage of ruminal contents at level L, as compared to level M, is consistent with the literature (Owens and Goetsch, 1988; Grimaud and Doreau, 1995) and involves a low volume of rumen fill at level L. Despite different levels and composition of intake between animals of groups LH and M, the weight of digestive contents, and also that of digestive tract was similar in these two groups. Indeed, the ratio between the weight of digestive contents and feed intake is lower with diets rich in concentrates like level LH than with forage-based diets like level M (Kouakou et al., 1997; Nozière et al., 1999), and the weight of digestive contents is a determinant factor for the weight of digestive tract (Rompala et al., 1988).

5. Conclusions

These results confirmed that the weight of splanchnic organs varies widely with undernutrition. Protein content of whole offals, lipid-free weight of these organs and ash content of organs rich in bone (feet and head) are affected by underfeeding and refeeding. However, extended and severe underfeeding results in a lower depletion and a lower variation of the weight of these organs compared to live weight loss. Nevertheless, owing to the high metabolic activity of splanchnic organs, the decrease in their mass leads to a decrease in energy requirements and contributes to the adaptation of these animals to a shortage in food, frequent in Barbary ewes in the Mediterranean area. Refeeding leads to increased weights of the different components of offal.

Acknowledgements

The authors are indebted to H. Marjouaa, N. Amari, J. Khil and T. M’Zougui for their technical help during this work.

References


