Clinical, haematological and biochemical evaluation of onion (Allium cepa) toxicity in goats

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SUMMARY

The effects of onion feeding on health were studied in goats. For this purpose, 12 clinically healthy female local-breed goats weighing 35-40 kg and 2-4 years old were randomly divided in 3 equal groups according to the onion amounts (0%, 30% and 60%) in diet for 60 days and clinical signs, haematological and biochemical parameters were regularly evaluated at 10 days intervals for 80 days. Except one goat fed with 60% onion in diet which died after respiratory distress and have exhibited hemosiderosis in liver, no relevant clinical signs were noted in goats fed with onions. Among haematological parameters, haematocrit and haemoglobin were significantly reduced according to the dietary onion supply, particularly on days 40 and 30 respectively and their variations were coupled to marked and significant increases in sideremia between the 30th and the 50th days in goats receiving 60% onion in diet. Additionally, serum phosphorus and urea concentrations were significantly enhanced in ruminants fed with 60% onion in diet. These results demonstrate that goats were more resistant to the onion toxicity than other livestock species and apart a transient haemolysis which has disappeared after removal of onion exposure, spring onions can be safely incorporated into diet up to 30% without any negative impact.

Keywords: Goat, onion, intoxication, haemolysis.

Introduction

Onions are herbaceous plants of Alliaceae family, widely cultivated in all over the world and the Central Asia is regarded as a centre of its domestication [4]. Onion bulb and spring onion are widely used in Iran, Pakistan and India and are essential to daily life in the local cuisine. If get access, livestock easily consumes onion often preferred to high quality roughages or grains [5, 12, 13]. However, ingestion of onions may result in haemolytic anaemia which is manifested by haemoglobinuria and icterus and characterized by Heinz body and eccentrocyte formation in most species of domestic animals [15]. Sources of onions include the feeding of culled onions to cattle, sheep and water buffalos [2, 3, 12, 13, 26], ingestion of wild onions by horses [16] and ingestion of raw, cooked, dehydrated onions and baby food containing onion powder by dogs and cats [6, 19, 22].

Onions and other plants of the Allium genus contain a wide variety of organosulfides, of which n-propyl disulfide and sodium n-propylthiosulfate are highly poisonous [6, 27]. These compounds are absorbed through the gastrointestinal tract and metabolized to highly reactive oxidants which are responsible for the oxidative damage in erythrocytes [6, 24]. Oxidative damage results in precipitation and aggregation of haemoglobin and its binding to the cytoplasm membrane, forming Heinz bodies. The Heinz body formation coupled to direct damage of the erythrocyte plasma membrane increases the osmotic fragility, leading to extra- and intravascular haemolysis [8].

Among livestock, cattle are more susceptible to the onion toxicity than horses, sheep and goats. Sheep may only show a slight haemoglobinuria [12, 20]. Younger sheep are also more susceptible than adults and this is in contrast to cattle in which adult ones are more susceptible to the onion toxicity than calves and yearling [25]. It has been shown that feedlot cattle can be fed with diets containing up to 25% culled onions on a dry matter (DM) basis. A decrease in packed cell volume (PCV) can occur because of the Heinz body related haemolysis but this parameter returns to usual values within 30 days after...
onion feeding is discontinued [15]. When ewes receive onions instead of alfalfa hay and grains, anaemia may develop within 3 weeks, although animals are clinically normal [13]. On the other hand, it has been shown that onions can be safely fed up to 50% to sheep without affecting fermentation in rumen or animal production and such feeding results in weight gains similar to those obtained from feeding with whole sorghum grains [10].

In Iran, more than 1.5 million metric tons of commercial onion bulbs are annually produced [9]. In most area, crop harvesting of onions is performed at late autumn when there are some restrictions in providing fresh forages for ruminants particularly for sheep and goats. So, culled onions and post-harvesting remnants of onion tops are occasionally used for sheep and goats feeding. Onion feeding in sheep in such situations can lead to development of Heinz body anaemia [2]. Nevertheless, according to the authors’ knowledge data concerning experimental onions feeding and safety in goats are not available, and the present study was conducted to evaluate haematological and biochemical aspects of onions feeding in goats.

Material and Methods

ANIMALS AND DIETS

Twelve clinically normal, female, non-lactating and non-pregnant goats weighing 35-40 kg, 2-4 years old and stemming from local breeds were purchased from a local market for the study. Goats were randomly divided into 3 equal groups and were housed in indoor pens. Prior to the beginning of the experiment, goats were dewormed by subcutaneous injection of ivermectin (0.22 mg/kg) and oral administration of rafoxanide (7.5 mg/kg) and fed under the aforementioned condition for 14 days to ensure proper acclimation. Whereas goats of the group 1 served as controls and received alfalfa hay, animals of groups 2 and 3 received diets contained 30% and 60% spring onions (on the DM basis) for 60 days, respectively. Fresh water was available ad libitum. Goats were observed daily for any signs of illness. They were also clinically examined at 10 days intervals. The experiment was approved by the Animal Welfare Committee of the School of the Ferdowsi University of Mashhad.

Spring onions were obtained every other day from a local bazaar to ensure freshness. Their DM ash, crude protein and crude fibre contents were determined by standard methods of proximate analysis [7]. The dry matter of spring onions was 7.5% and the ash, crude protein and crude fibre contents were 20.2, 22.8 and 10.8% respectively.

BLOOD SAMPLING, HAEMATOLOGICAL AND BIOCHEMICAL ANALYSES

Blood samples were collected from all animals by the jugular vein puncture into sterile microtubes with or without EDTA (ethylenediaminetetraacetic acid) as anticoagulant on Day 0 and every 10 days intervals until the 80th day (corresponding to the 20th day after cessation of onion feeding).

Cell blood counts (CBC) were determined using standard manual methods on whole blood samples within 24 hours. Blood samples without any anticoagulant were allowed to clot at room temperature for 30 minutes then centrifuged (2 000 g, room temperature, 10 minutes) and sera were carefully harvested and stored at -20°C until assayed. Plasmas were achieved by direct centrifugation (2 000 g, room temperature, 10 minutes) of whole blood EDTA samples and were stored at -20°C until assayed.

The total protein was determined by refractometry and the fibrinogen concentration was measured by the heat-precipitation-refractometry method. The other biochemical parameters (serum concentrations of glucose, albumin, cholesterol, total bilirubin, calcium, magnesium, phosphorus, zinc, iron, copper, urea, creatinine and serum aspartate aminotransferase (AST) and alkaline phosphatase (AP) activities) were measured by an automated biochemical analyzer (Biotechnica, Targa 3000, Italy) using corresponding commercial kits (Elitech, France, for zinc and copper and Pars Azmun, Iran for the other serum biochemical parameters). The serum selenium concentrations were determined by atomic absorption spectrophotometry (Perkin-Elmer 3030).

RESULTS

No significant clinical signs of toxicosis were observed in goats fed with onion diets. Goats receiving 60% onions in diet
showed strong onion smell in the breath. In addition, one goat of this group died on day 46 following respiratory distress for 2 days and this animal showed acute bronchopneumonia at necropsy. Histopathology revealed hemosiderosis in the liver.

Haematological parameters in goats according to onion feeding and the statistical effects of time, group and time x group interactions are presented in Table I. Although the total WBC, neutrophil and lymphocyte counts have significantly varied according to the time \((P < 0.05)\), no significant effect of the group and no significant time x group interaction were evidenced for these haematological parameters. By contrast, significant reductions in PCV and haemoglobin according to time \((P < 0.0001)\) and to the dietary regimen (time x group interactions: \(P < 0.02\) for PCV and \(P < 0.001\) for haemoglobin) were observed in goats fed with spring onions. In goats fed with spring onions (30% and 60% in diet), the PCV and the haemoglobinemia (Hb) began to slightly decrease compared to controls since the 20th day of the diet regimen and the highest differences were recorded at the 40th day for PCV (figure 1) and at the 30th day for Hb (figure 2): the PCV values differed from control values by approximately 18% and 25% and the Hb values by 34% and 37% in goats fed with 30% and 60% onions in diet, respectively. After the 40th day, the haematological parameters gradually increased in onion fed groups and became closely related to control values at the end of the experiment (on day 80, 20 days after that spring onion feeding was discontinued) except in the goats of the group 2 (30% onion diet for 60 days) in which a slight increase in haemoglobin compared to the anterior values and a marked and significant increase in PCV compared to control \((P < 0.05)\) and initial \((P < 0.05)\) values were noted. About 1 to 2% of red blood cells showed polychromasia (variation in the erythrocyte haemoglobin content) in goats receiving 30 and 60% spring onions in the diet on days 50 and 60.

The results of the biochemical analyses are shown in Table II. Significant time effects \((P < 0.05)\) for some parameters like circulating bilirubin, fibrinogen and calcium concentrations as well as serum ALP activity or only a tendency \((0.05 < P < 0.10)\) for proteinemia and serum Mg and Se concentrations were observed but were not associated with significant group effects. Although other parameters (serum cholesterol, albumin, Zn and Cu concentrations and serum AST activity) remained stable over the whole experimental period (no significant time effect), they have not presented any significant differences

<table>
<thead>
<tr>
<th>Haematological parameters</th>
<th>Groups (dietary onion content)</th>
<th>(P) values</th>
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<tbody>
<tr>
<td></td>
<td>0% (group 1)</td>
<td>30% (group 2)</td>
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<tr>
<td>PCV (%)</td>
<td>30.75 ± 2.78</td>
<td>30.31 ± 2.66</td>
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<tr>
<td>Haemoglobin (g/L)</td>
<td>109.3 ± 8.0</td>
<td>104.1 ± 7.7</td>
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<tr>
<td>WBC ((10^6/L))</td>
<td>9575.8 ± 1780.0</td>
<td>8493.0 ± 1636.0</td>
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<tr>
<td>Neutrophil ((10^6/L))</td>
<td>4095.9 ± 1516.3</td>
<td>4717.3 ± 1389.3</td>
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<tr>
<td>Lymphocyte ((10^6/L))</td>
<td>4760.0 ± 2026.0</td>
<td>3463.4 ± 1859.0</td>
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**PCV:** Packed Cell volume; **WBC:** White Blood cells.

*Statistically significant effects \((P < 0.05\) or more) were indicated in bold and statistical tendency \((0.05 < P < 0.10)\) in italic.*

**FIGURE 1:** PCV mean values (expressed in L/L) according to time in goats fed with 30% and 60% onions in diet for 60 days and in controls \((n = 4\) in each group). Results are expressed as mean ± standard error (SE). Different superscripts a,b,c for a given time point indicate significant differences \((P < 0.05\) or more) between groups.

**FIGURE 2:** Mean values of haemoglobinemia (expressed in g/L) according to time in goats fed with 30% and 60% onions in diet for 60 days and in controls \((n = 4\) in each group). Results are expressed as mean ± standard error (SE). Different superscripts a,b,c for a given time point indicate significant differences \((P < 0.05\) or more) between groups.
among groups. More interestingly, uraemia significantly fluctuated according to time \((P < 0.05)\) but a significant time x group interaction \((P < 0.05)\) was also obtained, dramatically elevated values being recorded in goats fed with 60% onions in diet. In the same way, the serum phosphorus concentrations were significantly influenced by group \((P < 0.0001)\), time \((P < 0.05)\) and time x group interactions \((P < 0.05)\) during the experimental period: they were significantly \((P < 0.01)\) increased in goats fed with 60% spring onion in comparison to the animals receiving 30% spring onions or no spring onions (Table II). On the other hand, although greatly affected by time \((P < 0.001)\), glycaemia tended to decrease in goats fed with 30% and 60% onions in diet \((P < 0.10)\) and creatinine concentrations were significantly declined in ruminants receiving 30% spring onions compared to controls \((P < 0.05)\). In addition, the sideremia was significantly influenced by time \((P < 0.02)\) and group \((P < 0.01)\). This parameter was significantly \((P < 0.01)\) elevated in goats receiving 60% spring onions in diet compared to the other 2 groups and the highest variations with controls were found on days 30, 40 and 50, the sideremia being increased by approximately 89%, 69% and 146%, respectively (figure 3).

### Discussion

Onion-induced haemolytic anaemia has been known for decades in various animal species. However, some species are more resistant to onion toxicosis than others. Among domestic animals cattle are more susceptible than dogs, horses, sheep and goats [5, 8, 15] and most of the reported cases of onion poisoning in livestock have occurred in cattle that have usually eaten cultivated or culled onions [12, 16, 17, 26]. On the other hand, it has been indicated that cattle performances were not affected by onion diets containing up to 25% onions [15]. In fact, it appears that toxicosis in cattle develops most often in cases of unlimited access and onion consumption over an extended period of time [12, 17]. In sheep, although it is concluded that those onion feeding has not any negative effect on animal

<table>
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<tbody>
<tr>
<td></td>
<td>0% (group 1)</td>
<td>30% (group 2)</td>
</tr>
<tr>
<td>Glucose (mmol/L)</td>
<td>4.39 ± 0.22</td>
<td>4.07 ± 0.19</td>
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<tr>
<td>Cholesterol (mmol/L)</td>
<td>1.05 ± 0.10</td>
<td>0.97 ± 0.09</td>
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<tr>
<td>Bilirubin (mmol/L)</td>
<td>7.44 ± 1.32</td>
<td>7.54 ± 1.20</td>
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<tr>
<td>Urea (mmol/L)</td>
<td>27.19 ± 0.14</td>
<td>26.47 ± 0.14</td>
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<tr>
<td>Creatinine (μmol/L)</td>
<td>89.68 ± 5.83</td>
<td>70.56 ± 5.39</td>
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<tr>
<td>Total protein (g/L)</td>
<td>76.69 ± 3.54</td>
<td>71.19 ± 3.31</td>
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<tr>
<td>Albumin (g/L)</td>
<td>34.44 ± 2.05</td>
<td>30.56 ± 1.93</td>
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<tr>
<td>Fibrinogen (mmol/L)</td>
<td>10.86 ± 1.57</td>
<td>9.31 ± 1.41</td>
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<tr>
<td>AST (U/L)</td>
<td>71.66 ± 0.08</td>
<td>71.95 ± 0.07</td>
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<tr>
<td>ALP (U/L)</td>
<td>76.17 ± 0.40</td>
<td>74.14 ± 0.38</td>
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<tr>
<td>Ca (mmol/L)</td>
<td>2.76 ± 0.06</td>
<td>2.71 ± 0.06</td>
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<tr>
<td>Mg (mmol/L)</td>
<td>1.31 ± 0.07</td>
<td>1.42 ± 0.06</td>
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<tr>
<td>P (mmol/L)</td>
<td>1.66 ± 0.10</td>
<td>1.37 ± 0.09</td>
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<tr>
<td>Fe (μmol/L)</td>
<td>16.42 ± 0.02</td>
<td>15.07 ± 0.01</td>
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<tr>
<td>Zn (μmol/L)</td>
<td>15.25 ± 0.04</td>
<td>12.84 ± 0.03</td>
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<tr>
<td>Cu (μmol/L)</td>
<td>30.27 ± 1.39</td>
<td>27.34 ± 1.25</td>
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<tr>
<td>Se (μmol/L)</td>
<td>1.17 ± 0.16</td>
<td>1.08 ± 0.15</td>
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**TABLE II:** Effect of onion feeding (30 and 60% of the diet) for 60 days on some biochemical parameters in goats \((n = 12)\). Results are expressed as mean ± standard error (SE).

**ASLANI (M.R.) AND COLLABORATORS**
performance [10], it has been shown that feeding with 33% and 50% onion diets lead to haemolysis reflected by decrease in PCV. In the current study, goats fed with spring onions showed some degrees of haemolysis, evidenced throughout reduction in PCV and haemoglobinemia. Goats fed with 30 and 60% onions in diet exhibited lower PCV and Hb values than controls. The red blood cell haemolysis in goats fed with 60% onions in diet was evident since the 20th day, whereas in goats fed with 30% onions diet, the haemolysis was slightly delayed on day 30 but in both cases, the erythrocyte destruction appeared maximal on day 40 and stopped when the onion feeding was discontinued. Even, the erythrocyte parameters have increased at the end of experiment (day 80) in goats fed with 30% onions in diet for 60 days, suggesting that erythropoiesis may be markedly stimulated by a limited haemolysis.

Onions and other plants of Allium family contain n-propyl disulfide and the amino acids S-meth- and S-prop(en)yl-cysteine sulfoxides (SMCO). It is generally admitted that onion haemolytic activity is due to their n-propyl disulfide content [5, 27]. Indeed, it was demonstrated that these compounds decrease glucose 6 phosphate dehydrogenase activity in erythrocytes leading to the decline in cellular NADPH amount which in turn curtails the regeneration of reduced glutathione needed to prevent oxidative denaturation of haemoglobin [24]. This process causes precipitation and aggregation of denatured haemoglobin which binds to the cell membrane and forms Heinz bodies in red blood cells. Other types of oxidation of haemoglobin chains result in membrane crosslinking reactions and eccentricyte formation. Direct oxidative damage to the erythrocyte cell membrane and its sodium – potassium pump or the oxidative production of haemin also occur. These oxidative changes increase erythrocyte fragility and extravascular haemolysis [6, 14, 18].

Simultaneously to PCV and Hb reduction in goats received 60% onion in diet, sideremia markedly increased and its decline was coupled to increases in haematological parameters observed after onion removal from the diet. The variations of the biochemical parameter were also compatible with extravascular haemolysis in which the Fe transfer from macrophages to plasma is increased [21]. Elevation of serum phosphorous concentration may be an indication of haemolysis along with renal damage. Various degrees in haemolysis can also indirectly lead to some renal damage due to prolonged nephrocyte exposure to haemoglobin. In this way, uraemia has greatly fluctuated according to time, mainly in goats fed with 60% onion in diet. It is also possible that iron overloading in macrophages can interfere with liver function and particularly can partially counteract the gluconeogenesis, leading to a low glycemia as observed in goats exposed to the onion rich diet. Indeed, clinical signs of onion toxicity described in cattle [12, 17, 25, 26], water buffalos [3], horses [16], dogs [6, 11, 23] and cats [6] including pale and icterus mucous membranes, haemoglobinuria presented as dark brown urine, anorexia, tachycardia and tachypnea suggested systemic lesions and particularly liver and kidney injury. Consumption of only 5 g/kg of onions in cats or 15–30 g/kg in dogs has resulted in clinically important haematological changes [6]. The results of experimental onion feeding in cattle have been indicated that the 25% (DM) onion diet is probably the toxic threshold for onion consumption in this species [15]. Sheep can also be maintained on a diet of up to 50% onions without any clinical abnormalities or considerable effects on growth [10]. However, when onion is fed ad libitum, sheep exhibited transient haemoglobinuria and anaemia, and few deaths have been reported [2, 13]. However, although haemosiderosis in liver was noted in one goat fed with 60% onion diet, the clinical incidence of onion toxicosis in goats was appeared reduced in the present study since no obvious clinical signs were detected in the great majority of animals exposed to onions.

The safety of animal feeding with onions depends upon the susceptibility of animal species and the onion potential toxicity linked to the amounts of SMCO and other disulfides [10, 17] depending from the plant varieties. More than 15 onion genotypes are cultivated in Iran [1] and differ in taste and probably in toxicity. In addition to the species susceptibility and to the variable onion contents in toxic compounds, the interactions between nutrients and toxic compounds may also play an important role in the course of intoxication, a low quality food probably promoting the deleterious onion effects and death [10].

As a conclusion, under the conditions of the present experiment, it seems that up to 30% spring onions in diet can be consumed relatively safely by goats without any clinical toxicity whereas some clinical complications and a more marked haemolysis can occur when diets containing 60% of onions were used. Additionally, goats can tolerate much more onions in diet than other livestock species.

Acknowledgment

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References


